# The Africanized Honey Bee in the United States

## What Will Happen to the U.S. Beekeeping Industry?

Robert McDowell

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## Abstract

The U.S. beekeeping industry may experience annual losses of $26 million to $58 million if the Africanized honey bee (AHB) colonizes the South and Southwest and causes the kinds of problems it has caused elsewhere. If the AHB colonizes the area that has at least 240 frost-free days a year, losses could range from $49 million to $58 million annually, depending on the behavior of the bee. If the AHB colonizes the area south of latitude 32° North, the economic losses could range from $26 million to $31 million annually, depending on the behavior of the AHB. Every aspect of beekeeping—honey and beeswax production, queen and package bee production, pollination, and migratory beekeeping—could be adversely affected.

Keywords: African honey bee, Africanized honey bee, *Apis mellifera adansonii*, economic impacts, beekeeping, bee industry economics, queen and package bee production, migratory beekeeping, almond pollination, honey and beeswax production, *Apis mellifera scutellata.*

## Acknowledgments

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## Preface

This report was prepared in response to a request from the U.S. Congress "to assess the economic significance that this strain [African honey bee] would have if it became established in the United States..." (*52*).

# Highlights

The Africanized honey bee (AHB) has successfully colonized much of South America and is now as far north as Costa Rica; no known obstacle will prevent its colonizing the warmer areas of the United States. The U.S. beekeeping industry may experience annual losses of $26-$58 million if the AHB colonizes the Southern and Southwestern United States and causes the kinds of problems it has caused in South America.

This report assesses the potential economic effects on honey and beeswax production, queen and package bee production, migratory beekeeping, and almond pollination that could accompany four possible scenarios of the AHB's establishment in the United States:

• *Scenario I.* The AHB colonizes parts of 11 Southern and Southwestern States that have at least 240 frost-free days annually. Most producers of queen bees and package bees are in this area. It is also an important wintering area for migratory beekeepers who move their bees south in the winter and return north for the summer. The AHB will exhibit the same type of behavior observed in northern South America. Annual losses of $54-$58 million could occur if the AHB colonizes this area. The estimated annual losses are as follows: about 90 percent of the queen and package bee industry would be affected, resulting in revenue losses of $14 million; declining honey and beeswax yields would reduce beekeepers' revenues by $22-$27 million; banning migratory beekeeping could cost beekeepers $13 million in extra operating costs; beekeepers pollinating almonds would lose almost $1.4 million in pollination fees and inadequate pollination could reduce almond growers' revenues by $2.6 million.

• *Scenario II.* The AHB colonizes the same area as in Scenario I, but loses its aggressive behavior. Losses could total $49-$52 million annually. Losses in queen and package bee production, migratory beekeeping, and almond pollination are the same as in Scenario I. Declining honey and beeswax production could reduce revenues by $17-$20 million annually.

• *Scenario III.* The AHB colonizes the area of the United States south of latitude 32° North (except for the small portions of Arizona and New Mexico south of latitude 32° North), and retains its aggressive behavior. The losses to beekeepers could total $29-$31 million annually. Revenues from queen and package bee sales could decline by about $7 million annually. Declining honey and beeswax production would reduce annual revenues by $13-$15 million. Banning migratory beekeeping would increase beekeepers' annual operating costs by $9 million.

• *Scenario IV.* The AHB colonizes the same area as in Scenario III, but loses its aggressive stinging behavior. Because of this behavior modification, losses are slightly lower than in Scenario III, totaling $26-$28 million annually. The losses in queen and package bee production and to migratory beekeeping are the same as for Scenario II. Declining honey and beeswax yields would reduce beekeepers' revenues by $10-$12 million annually.

Economic effects were estimated using USDA statistics on colony numbers, honey and beeswax yields, and 1981 prices. The specific data necessary to estimate how the AHB would affect U.S. beekeeping are not available. The effects were estimated using a number of assumptions about how the AHB would affect

the biological productivity of ordinary honey bees, and how beekeeping, the general public, and State and Federal regulatory agencies would respond to the problems generated by the AHB.

The author did not estimate the effects on public health, pollination (except almonds), beekeeping supply and equipment firms, nonmigratory beekeeping in the AHB-free States, and beekeepers in other countries that depend on the Southern United States for queen honey bees and package bees.

## Glossary

*Brood*—Bee larvae and pupae.

*Divide*—Part of a larger bee colony. Used for increasing the number of colonies in order to increase honey production. Generally, two to five frames of adult bees, brood, and a queen. Also referred to as nucleus colony or split.

*Drone*—A male bee which is stingless and which performs no work.

*Frame*—That part of a hive which holds honey comb.

*Larvae*—Newly hatched bees.

*Nucleus colony*—Same as "Divide" above.

*Package*—2- to 5-pound container of adult bees, a queen bee, and a small amount of sugar syrup to feed the bees during shipment.

*Propolis*—A glue-like substance collected by bees from the buds of trees.

*Pupa*—An inactive stage of bee development during which the bee undergoes a metamorphosis, changing from a larva to an adult.

*Royal jelly*—A substance produced by worker bees that is fed to bee larvae. Bees produce queens by feeding selected larvae large quantities of royal jelly, hence the term.

*Split*—Same as "Divide" above.

# The Africanized Honey Bee in the United States: What Will Happen to the U.S. Beekeeping Industry?

## Robert McDowell*

## Introduction

The general public has a special fear of stinging insects and a particularly morbid fascination with hordes of stinging insects. A number of sensational news stories and motion pictures about the Africanized honey bee (AHB), also known as the Brazilian bee and the "killer bee" (a misnomer) have played on this fear. The result has been a mixing of fact, fiction, myth, and misinformation to the detriment of a wider, clearer understanding of the issue. The AHB is also a controversial topic among bee researchers and beekeepers. Although the bee has been in South America for almost 30 years and its potential economic effects on U.S. beekeeping and agriculture have been the subject of speculation, those economic effects have not been systematically evaluated.

This report describes and measures some of the possible economic effects if the AHB permanently colonizes parts of the United States and behaves as it has in South America. This report includes a review of some of the AHB literature, a brief description of the U.S. beekeeping industry, and preliminary estimates of the economic impacts of the Africanized honey bee in the United States.

The economic effects were estimated for four AHB infestation scenarios which include two potential geographic ranges and two types of AHB behavior. The analysis draws on U.S. Department of Agriculture (USDA) statistics for bee colony numbers and honey production, two projections of the potential range of the AHB in the United States, and assumptions about the biological and social impacts the AHB could have in the United States. These assumptions were based on how the AHB has affected beekeeping in South America and on the predictions and opinions of professional apiculturists. Losses were estimated for honey producers, queen and package bee producers, migratory beekeepers, beekeepers who rent bees to pollinate almonds, and almond growers.

## Background on the Africanized Honey Bee

In 1956, Brazilian researchers imported honey bee queens of the race *Apis mellifera adansonii*[1] from Africa. Their objective was to develop a honey bee more suited to conditions in tropical South America than are the European races of honey bees. In 1957, swarms of the African bees escaped from 26 colonies

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[1]Some researchers classify this honey bee race or subspecies as *Apis mellifera scutellata.* However, much of the literature refers to it as *A.m. adansonii,* and this report follows that convention.

located in the State of Sao Paulo, Brazil. These bees multiplied quickly and have since spread over much of South America, interbreeding with the existing honey bees as they dispersed (27).[2] The rapid spread of the AHB and its effects on beekeeping and public health in South America generated considerable interest among beekeepers and the general public elsewhere. This interest has been encouraged by the "repeated and sometimes lurid references to the introduction of African honey bees into South America, to the spread of such bees or their hybrid descendants (Africanized bees, i.e. the Brazilian honey bees), and to the influence of such bees on apiculture, pollination, animal husbandry, and public health in South America, and prospectively, in North America" (26). Some of the reports in the popular press were clearly sensational, creating confusion among the public and beekeepers about the actual nature of the AHB problem (39).

## Geographic Range

The current range of the AHB in the Western Hemisphere extends from Argentina (16) to Panama (5) (figs. 1 and 2). Researchers have concluded there is no presently known obstacle that will prevent the AHB from spreading through Central America, Mexico, and into the United States (41). Taylor accurately predicted the spread of the AHB through northern South America; if his predictions for the spread of the AHB through Central America and Mexico (fig. 2) are correct, the AHB could reach the United States within a decade (41).

Based on the climatic range the AHB has successfully colonized in South America, Taylor predicts that the AHB may permanently colonize the area of the United States that has at least 240 frost-free days annually (fig. 3) (41). Other boundaries of the area which may be colonized by the AHB have been suggested, such as the 210-frost-free-day area and the area where winter temperatures do not fall below − 10 °C (14 °F). Others have focused on the geographic range (as opposed to climatic range) of the AHB in Argentina, where the AHB-area extends to about latitude 32°-33° South. Based on this observation, some have suggested the AHB will not be able to colonize the United States north of latitude 32° North (fig. 3).

Apiculturists dispute the area of the United States that could be colonized by the AHB and the potential effects (27, 29, 40). The current distribution of the AHB in Argentina is still a matter of speculation (16), and the

effect of the AHB on beekeeping in Argentina is also not well understood in the United States. Most U.S. apiculturists actively involved in AHB research believe the AHB may become a serious problem to beekeeping in the United States. However, a few bee specialists dispute the hypotheses that the AHB will colonize much of the United States, and that it will cause any significant problems even if it does colonize parts of the United States (29, 40). The authors of a review of the history of bee importations concluded that honey bee queens from various parts of Africa were imported to Europe and North America at various times without causing any noticeable problems (30). However, a group of scientists appointed by the U.S. National Academy of Sciences concluded that the AHB poses a serious threat to beekeeping in the United States, particularly the queen and package bee industry and pollination activities (27).

A USDA-sponsored study of the AHB is being conducted in Argentina. This and other research also underway will improve our understanding of how the AHB may influence beekeeping in a temperate climate. As new data become available, researchers may alter their predictions of the potential range, behavior, and effects of the AHB in the United States.

## Behavior

How the AHB will behave when and if it reaches the United States is far from certain. The experience with the AHB in temperate South America appears to have been somewhat less traumatic than in the tropical and semitropical parts of South America. However, researchers are unwilling to predict to what extent AHB behavior might be modified by the time the AHB reaches the United States (7).

The AHB has affected public health and beekeeping in South America, but the seriousness varies by location and with the source of information. There have been increased encounters with swarms and reports of human and livestock deaths from mass stinging incidents. Despite the problems beekeepers and the general public have had with the AHB, it is not a major public health hazard in South America nor is it expected to become one in the United States (27, 42).

In some areas, beekeeping and honey production declined because as many as 80 percent of the amateur beekeepers abandoned their colonies, up to 20 percent of the commercial beekeepers quit beekeeping, and honey production by the remaining colonies declined (8). In Venezuela, honey production declined to 20 percent of its former level after the AHB became wide-

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Figure 1

## Expansion of the Area Occupied by the Africanized Honey Bee in South America, 1957-77



a/ The 10°C line (━━━) is the mean temperature during the coldest month.

Source: (41). Reproduced by permission.
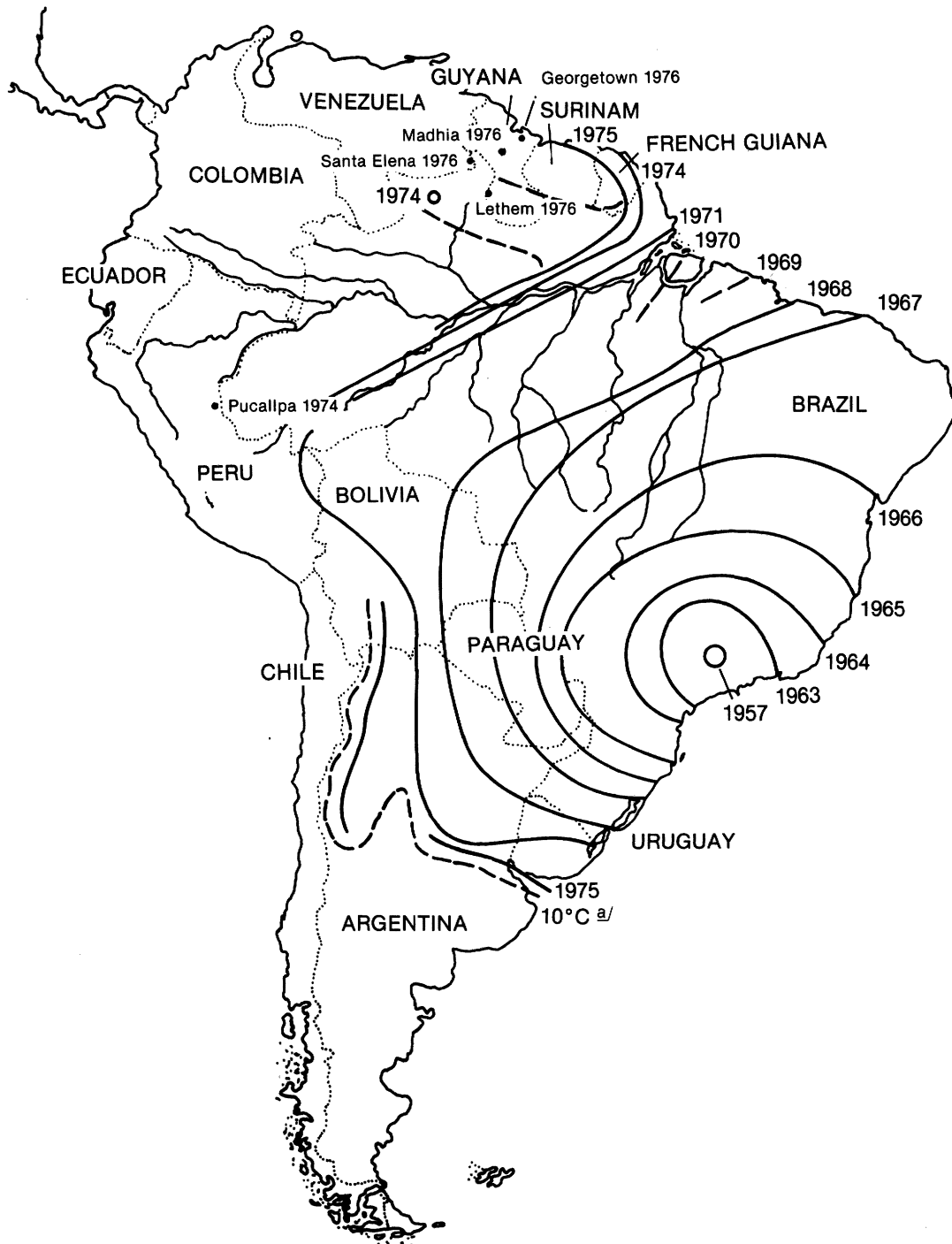
Figure 2

## Predicted Spread of the Africanized Honey Bee
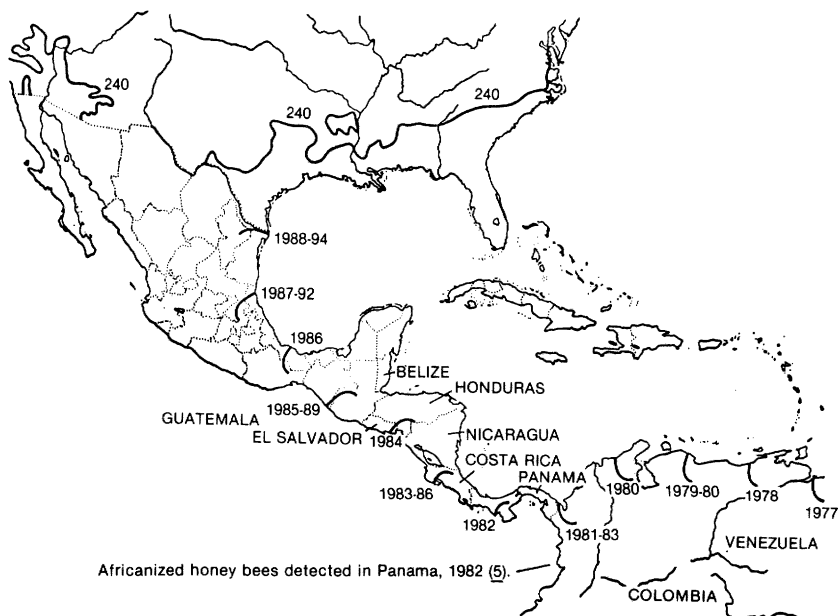


Source: Frank A. Robinson. "Africanized Bees: A Problem that Won't Go Away!" *American Bee Journal,* Vol. 121, No. 9 (Sept. 1981), 625-26. Reproduced by permission.

Note: The arcs represent the leading edge of the infested area, by year. The solid line in the United States is the 240-frost-free-day line. The note on the detection of Africanized honey bees in Panama was added by the author.

Figure 3

## Climatic Factors and the Possible Northern Limits for the Africanized Bees in North America



– 10° C (lowest temperature expected annually)

240 frost-free day (length of growing season)

210 frost-free day (length of growing season)
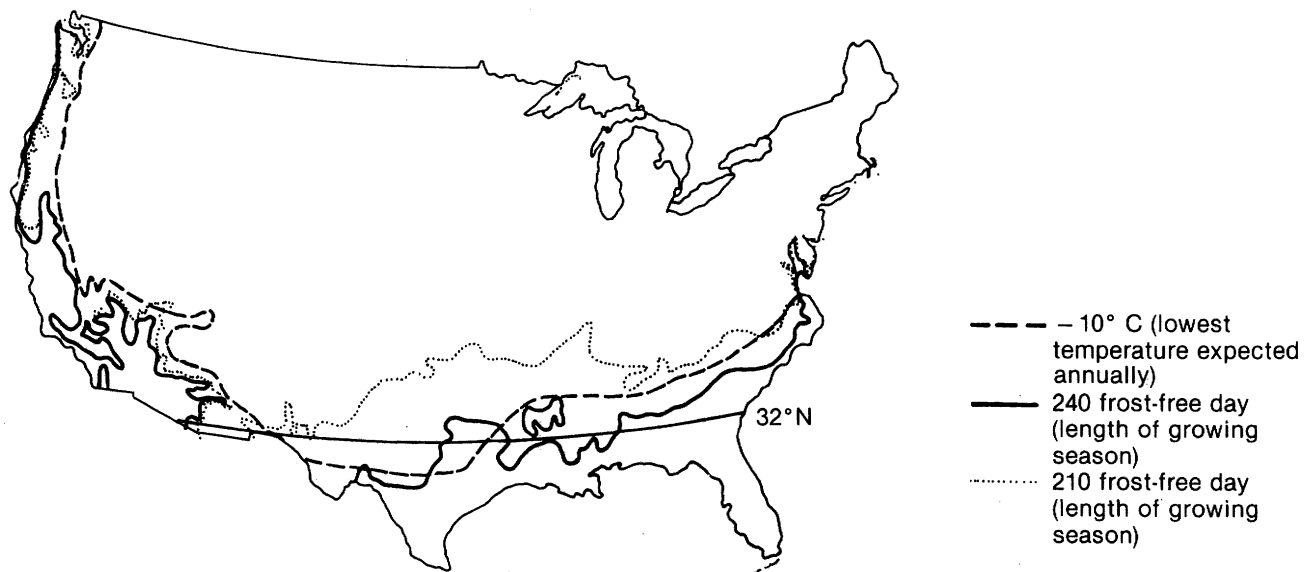
Source: (41). Reproduced by permission.

spread (*54*). Although the AHB is implicated in changes in honey production, other factors including weather, destruction of forests, and increased pesticide use (especially on cotton) may have contributed to reduced honey production (*26*).

The factors contributing to these negative effects stem from biological and behavioral traits the AHB evolved in response to climate and biological conditions in Africa. Recent findings by USDA researchers working in the United States and Venezuela indicate that the AHB, as it currently exists in Venezuela, is significantly different from the European honey bee (EHB) used in the United States.

A report by the U.S. National Academy of Sciences on the AHB identifies a number of problem traits (*27*):

• *Aggressive hive defense and stinging:* USDA researchers have found that AHB's "respond to colony disturbance quicker, in greater numbers, and with more stinging." AHB colonies produced six to eight times more stings than EHB colonies in tests using similar size colonies under similar environmental conditions (*7*). How the AHB would respond in the more temperate part of the United States is not certain because the defensive behavior may be modified by environmental conditions.

• *Excessive swarming:* When a bee colony swarms, about half the bees in the colony leave with the queen to relocate in a new domicile. Swarming is the way bee colonies multiply and is common to all races of honey bees. However, the AHB swarms much more frequently than the EHB. When a colony swarms, its population is significantly reduced. Because a colony's productivity is proportional to its population, reductions in population lower the capacity of the colony to produce honey or to pollinate. Swarm control is labor intensive, a critical task of beekeeping, even with EHB's; managing honey bees that swarm frequently would increase labor costs for commercial beekeeping firms.

• *Excessive absconding:* When a colony absconds, the entire colony leaves the original nest and moves to a new location. Absconding is rare in EHB's but is common to AHB's (*10*). Absconding by the AHB is an adaptation to periodic food shortages; rather than remain in the same location and starve, AHB's attempt to move to an area where food is more plentiful. In the same situation, EHB's usually remain in the original nest and consume their food reserves until they either starve or more food becomes available.

• *Robbing honey from other colonies:* Robbing is a type of foraging behavior in which bees forage or rob honey from other colonies. Robbing is a problem when natural sources of nectar are not available. This behavior makes manipulating colonies difficult because exposing combs containing nectar and honey stimulates bees to begin robbing; an episode of robbing may actually kill weak colonies if their food reserves are robbed. A large number of bees are often killed during robbing, which can also spread diseases and parasites.

• *Lack of selectivity in choosing a nest site:* Compared with EHB's, the AHB will nest almost anywhere it is protected from the weather. The EHB, except for rare occurrences, nests only in cavities above ground. This lack of selectivity about nesting sites may simply result from large feral populations (swarms which have established themselves in the wild) that arise due to the AHB's high reproductive rate and frequent swarming. Because ideal nesting sites are limited, large populations result in many colonies selecting less than ideal nesting sites.

• *Large numbers of feral colonies:* Feral colonies compete with managed colonies and wild bees for food resources. Feral bees also pose a problem for managing bee diseases and parasites. Feral AHB colonies are a source of large numbers of drone honey bees (males) that tend to saturate an area, maintaining a high degree of Africanization in local honey bee populations.

• *Poor winter survival in cold climates:* The AHB may not be able to regulate its body temperature as efficiently as the EHB. Although AHB's have not been subjected to the evolutionary pressure of prolonged periods of cold weather, they do cluster during cold weather and can survive extended cold periods. Perennial colonies (that is, permanent colonies that persist year round) of *Apis mellifera adansonii* have been found at high altitudes in the mountains of South Africa where the absolute minimum temperature is below freezing for 6 months a year, and snow lasting a week at a time is not uncommon (*10*).

• *Colony takeover:* Many researchers have reported that AHB swarms often take over EHB colonies, particularly colonies that do not have functional queens (*26*). This phenomenon is particularly threatening to the U.S. queen-rearing industry which uses small colonies or nuclei to produce mated queens. These colonies are usually left queenless for short periods of time to enhance the probability that virgin queens introduced to them will be accepted. The importance of takeover in the spread of the AHB and in managing bees in AHB-infested areas is not certain.

• *Suspected mating advantage:* Within 2-3 years after the AHB enters an area, most bee colonies exhibit AHB traits. Because EHB queens appear to mate with AHB drones at a much higher frequency than AHB queens do with EHB drones, the EHB gene pool is modified much more than the AHB gene pool. This has been observed in South America where AHB's from northern South America showed little evidence of hybridizing with EHB's as the AHB's moved northward from Brazil. Detailed analyses of the bees from northern South America found the AHB's to be essentially unchanged from the bees that were first imported to South America in 1956 (8). It is not known if this will also occur as the AHB moves through Mexico where it will encounter large populations of EHB's maintained by beekeepers.

The limited impact on the EHB on African honey bee populations has also been noted in Africa. In Pretoria, South Africa, where the native honey bees (*Apis mellifera adansonii*) have had prolonged exposure to imported EHB's, the *A. m. adansonii* populations appear to have been genetically unaffected by the exposure to the imported bees. A number of factors are believed to be responsible for the quick elimination of foreign genes from the *A. m. adansonii* gene pool (10).

• *Unpredictable behavior during hive inspection:* In addition to the more aggressive colony defense displayed by AHB's, the bees tend to run on the combs, form clumps, hang from the combs (known as "festooning"), and in general act in an agitated manner when AHB colonies are examined. This behavior complicates practices such as requeening or finding queens in mating nuclei because queens are harder to find when bees are active. By contrast, EHB's tend to be more docile and move about less when colonies are examined.

The behavior of the AHB appears to be more moderate after the bees have been in an area for an extended period of time. Most bee colonies are Africanized in Brazil, and beekeepers there have adapted to the AHB and now produce good crops of honey.[3] However, frequent swarming is still a major problem. Most colonies are manipulated infrequently due to the aggressiveness of the bees and their propensity for robbing. Robbing is especially a problem when there are many colonies in a single bee yard (18). These conditions would impose serious restrictions on commercial beekeepers in the United States where the economics of beekeeping are such that a number of colonies must be kept in each bee yard for profitable honey production.[4]

## The U.S. Honey Bee Industry

The U.S. honey bee industry produces honey, beeswax, honey bee queens, and package bees, and also provides pollination services (mostly free, but also on a fee basis). An economically significant activity of commercial beekeeping is an annual migration south for the winter where colonies continue to produce honey, are used for pollination, and are divided to increase colony numbers and replace losses due to pesticides and other causes.

There are beekeepers in every State (fig. 4), but commercial production is concentrated in about 20 States. Of the estimated 4.1 million colonies in the United States, half are operated by about 1,600 commercial beekeepers (defined as operating 300 or more colonies), and the other half are operated by an estimated 200,000 hobbyists (1-24 colonies) and 10,000 part-time beekeepers (25-299 colonies) (51).

### Honey and Beeswax Production

Honey production is the primary economic base of the U.S. beekeeping industry. Honey is produced in all States, but nine States account for more than half the total U.S. production (fig. 5). California, Florida, and Texas—all of which could be colonized by the AHB—account for about one-quarter of U.S. honey production. Minnesota, Montana, North Dakota, South Dakota, and Wisconsin account for about one-quarter of U.S. honey production. Honey production fluctuates substantially from year to year, due primarily to weather conditions. The 1975-79 average honey production was about 209 million pounds annually, valued at about $130 million per year. Beeswax is produced coincidentally with honey; U.S. production averaged about 3.5 million pounds annually from 1975-79, valued at about $5.2 million per year (48).

### Queen and Package Bee Production

The queen and package bee business is a service industry to the rest of the beekeeping business. Queen honey bees and package bees (a package is sold as 2-5 pounds of honey bees with a queen) are produced in California, Texas, and the Gulf Coast States. Packages are sold primarily in the spring to beekeepers in the

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[3]An important factor in the growth of the Brazilian honey industry since the AHB outbreak there has been the establishment of large citrus orchards which are superb nectar sources for producing honey.

[4]One large U.S. beekeeping firm regards 40 colonies per bee yard (apiary site) to be the minimum stocking rate for profitable production (33).

Northern States and Canada to establish new colonies, replace colonies killed in the fall, colonies that died during the winter, and colonies damaged or killed by pesticides or diseases. Queens are sold in spring, summer, and fall to replace existing queens and to increase the number of colonies. Although the primary market is northern beekeepers, U.S. producers ship queens worldwide.

Package bees, queens, and nuclei can be produced in Northern States, but not at the time of year when northern beekeepers need them. Warm weather, inducing plants to flower and produce pollen and nectar, is required to stimulate bee colonies to rear brood. Weather warm enough to permit bee flight is also necessary to produce drones and to mate queens. Thus, southern beekeepers can produce package bees and queens several months before northern beekeepers can do so.

Statistics on current U.S. queen and package bee production are not available. A survey in 1969 concluded annual U.S. production exceeded 1 million queens and 500,000 2-pound packages (34).[5] These estimates do not include queens and packages produced and used in the same beekeeping firm.

### Migratory Beekeeping

Many commercial beekeepers move bee colonies to the South and Southwest for the winter. These colonies are used to produce honey, to pollinate crops such as melons and almonds, and to make nucleus colonies that are moved north in the spring for honey production and pollination. Several hundred thousand colonies are moved each year for these purposes. In areas where winter losses are high, many beekeepers kill a portion of their colonies in the fall, remove all the honey, and move the remaining colonies south for the winter. By migrating, they can produce honey in the South, overwinter fewer colonies, pollinate crops for a fee, and produce their own queens and nucleus colonies.

### Pollination

Honey bees are the primary pollinators of the $5-$6 billion in fruit, vegetables, legumes, and fiber produced annually that require or benefit from bee pollination (11, 20, 53) (see app.1). Some beekeepers provide pollination services for a fee; however, the revenues received for pollination services are small compared with the value of honey and beeswax sales. Pollination for a fee is limited to those areas of the country where large acre-

ages of bee-pollinated seeds, fruits, and vegetables are grown. A number of commercial beekeeping firms on the Pacific Coast and in parts of Texas, Florida, and the Mid-Atlantic States earn part of their income from pollination rentals. Renting bees for pollination is uncommon in most other areas, and most beekeepers do not earn any revenue from it (14).

The economic value of bee pollination to crop producers far exceeds the total revenue of the beekeeping industry from all sources. For example, the average value of the U.S. almond crop—which relies on honey bee pollination (23)—was about $450 million annually, 1979-81 (48). The average value of U.S. honey production for the same period was about $130 million (48), less than one-third the value of the almond crop.

## Research Methods and Assumptions

Aggregate projections of the total economic effect of a permanent AHB infestation were developed by estimating the economic effects for the major sectors of the U.S. honey bee industry: queen and package bee production, honey and beeswax production, migratory beekeeping, and pollination. The effects on honey and beeswax production were estimated separately for commercial and hobby/part-time beekeepers. The partial economic effect on pollination activities was estimated for one sample crop, almonds. No estimates were made of the economic impacts on commercial beekeepers in Northern States who do not move their colonies south in the winter. It was assumed that these beekeepers will alter their management practices (for example, requeening in the late summer or fall) to overcome the problems imposed by a lack of good queens and packages in the early spring.

### Assumptions

The following assumptions were made to model the potential biological and economic effects of an AHB infestation.

1.  To protect the honey bee industry outside the areas colonized by the AHB, a quarantine will be imposed on all live bee shipments from the AHB area. This will include queens, package bees, nuclei, and complete colonies. Because of the expected dynamic nature of the infestation, there will be no practical way to inspect and certify AHB-free areas within infested States. Thus, the quarantine is assumed to include the entire State, prohibiting the export of live bees from any State inhabited by the AHB.

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[5]Package bees are sold by weight in sizes ranging from 2-5 pounds. The production estimates are based on total production and include all package sizes.

2. Bee management problems, restrictive legislation, and reduced honey yields will force some hobby and part-time beekeepers to quit beekeeping. It is assumed that in doing so they will abandon or kill their colonies.

3. In the area colonized by the AHB, the combination of swarming, absconding, loss of apiary sites, and competition from feral colonies will cause honey and beeswax yields to decline by 30 percent. This decline is assumed to apply to all colonies in the area colonized by the AHB.

4. The economic analysis assumed 1981 prices and current technology. Hence, long-term queen storage, large-scale artificial insemination, enclosed queen mating, indoor queen and package production, and other laboratory or hypothetical techniques were not evaluated as practical solutions to the problems generated by the AHB.

## Rationale for Assumptions

The assumptions about potential regulatory actions are not official USDA or State positions on, or contingency plans for, the AHB. In developing the assumptions, a distinction was made between the abilities and potential reactions of commercial beekeepers, part-time and hobby beekeepers, and the general public.

For commercial beekeepers, the problems associated with AHB-behavior are not likely to pose insurmountable difficulties. Commercial beekeepers will probably be able to alter management practices and adapt to keeping bees in an area infested with AHB.[6] However, this will be difficult for many amateur beekeepers. Many hobby and part-time beekeepers faced with these problems will probably not have the skill, time, money, or inclination to adapt to the AHB.

The major problem will probably be the general public. Stinging incidents, swarming, AHB's nesting in sites EHB's will not nest in, and the general public reaction that may accompany the entry of the AHB into the United States will have a major effect on the beekeeping industry. In areas favorable to the AHB, beekeepers may face zoning ordinances prohibiting beekeeping, other laws restricting apiary sites, and an increased liability to lawsuits from bee incidents. Because of

these restrictions, many hobby and part-time beekeepers will probably go out of business, either abandoning or killing colonies. The combination of legal restrictions, management problems, low honey yields, and a lack of suitable apiary sites may also prevent commercial beekeepers from expanding or maintaining their current colony numbers.

Outside the area colonized by the AHB, the reaction of the general public, resident beekeepers (hobby and commercial), and others interested in protecting the bee industry in their States will provide a strong incentive to keep the AHB out of their area. Their objectives will be to avoid the negative publicity, the restrictive legislation that will accompany this publicity, and the other problems of managing the AHB.

The general public is frequently unable to adequately evaluate news stories about the AHB. Also, many persons cannot distinguish honey bees from other stinging insects such as wasps, yellow jackets, hornets, and other types of bees. As a consequence, adverse public reaction to news stories about bee incidents (coupled with a general fear of insects and stinging insects in particular) has already led to restrictive regulations and the loss of apiary sites (39).

The package and queen industry currently relies on producing naturally mated queens. However, producing naturally mated queens of known genetic stock in an area colonized by the AHB may not be possible. Many northern beekeepers may not want to purchase queens from areas that may have the AHB. Furthermore some States may impose quarantines to prevent the spread of the AHB. As a result, the package and queen industry may face significant problems marketing naturally mated queens that may be contaminated by AHB genes.

## Africanized Honey Bee Scenarios

There is a lack of specific data and general agreement among professional apiculturists about the basic issues of an AHB infestation (such as absconding, swarming, labor problems, and apiary sites). Thus, the author developed four scenarios to estimate potential economic effects on specific sectors of the beekeeping industry if the AHB permanently colonized parts of the United States.

The four scenarios are based on two geographic areas (fig. 3) (the area with at least 240 frost-free days annually and the area south of latitude 32° North) and two general models of Africanized bee behavior (typical AHB behavior and modified AHB behavior).

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[6]See app. 2 for how the AHB could affect commercial beekeepers in the areas where it becomes permanently established.

Typical AHB behavior is defined as including the objectionable traits discussed earlier in this report. The modified AHB behavior is defined as having all the objectionable traits except for the aggressive hive defense and stinging and generally unpredictable behavior.

## Scenario I

Scenario I assumes that the AHB with typical Africanized behavior will inhabit the area that has at least 240 frost-free days annually (fig. 3) and includes parts of 11 States (table 1).

### Queen and Package Bee Production

There are no current, reliable, published statistics on the volume and value of queen and package bee production. Also, there are no reliable data on where these queens and packages are shipped (for example, by State, foreign countries). Estimates of package bee production range from 500,000-800,000 2-pound packages annually, and queen production has been estimated at 1.0-1.8 million annually (22, 34).

This analysis conservatively assumes that U.S. queen and package bee production totals 1 million queens and 500,000 2-pound packages (with queen) annually. At current prices, the annual value of this industry is estimated as follows:

$$
\begin{array}{rcl}
\text{1 million queens @\$6.00} & = & \text{\$6 million} \\
\text{500,000 2-pound packages @\$20.00} & = & \underline{\text{\$10 million}} \\
& & \text{\$16 million}
\end{array}
$$

Approximately 90 percent of the U.S. queen and package bee production is located in the 11 States assumed to be colonized by the AHB (41). A quarantine on live bee shipments would eliminate package and queen shipments from these 11 States. Assuming 90 percent of the queen and package industry is so affected, the loss is estimated as 90 percent of the value of production, or $14.4 million annually.

### Honey and Beeswax Production

There are about 1.7 million colonies of honey bees in the 11 affected States; slightly more than half of these colonies are operated by commercial beekeepers (table 1). During 1975-79, honey production averaged about 73 million pounds per year, and beeswax production averaged about 1.2 million pounds per year. Using 1981 U.S. season-average prices ($0.62 per pound for honey, $1.91 per pound for beeswax) (48), the value of this average production was about $45 million for honey and about $2.3 million for beeswax.

**Table 1—Scenarios I and II: Bee colonies and honey production in affected States, 1975–79 average**

| State | Number of colonies[1] | | | Honey production | |
| | Hobby/ part-time | Commercial[2] | Total | Per colony | Total |
| --- | --- | --- | --- | --- | --- |
| | --------1,000 colonies-------- | | | Pounds | 1,000 pounds |
| Alabama | 23 | 23 | 46 | 21.0 | 966 |
| Arizona | 12 | 47 | 59 | 50.0 | 2,983 |
| California | 128 | 384 | 512 | 39.0 | 20,037 |
| Florida | 180 | 180 | 360 | 66.0 | 23,634 |
| Georgia | 40 | 115 | 155 | 27.0 | 4,264 |
| Louisiana | 22 | 12 | 34 | 37.0 | 1,260 |
| Mississippi | 28 | 27 | 55 | 26.0 | 1,410 |
| North Carolina | 186 | 10 | 196 | 25.0 | 4,824 |
| South Carolina | 67 | 12 | 79 | 18.0 | 1,040 |
| Texas | 99 | 100 | 199 | 52.0 | 10,284 |
| Virginia | 43 | 13 | 56 | 26.0 | 1,988 |
| Total | 828 | 923 | 1,751 | 41.4[3] | 72,690 |

[1]Includes colonies operated for honey production, does not include colonies used for package bee and queen production.

[2]Includes colonies in beekeeping operations with more than 300 colonies. The number of commercial colonies in Alabama, Louisiana, Mississippi, South Carolina, and Virginia were derived from USDA estimates of total colony numbers.

[3]Average production per colony in affected States.

Source: (45, 46, 47).

The author assumed that 50-80 percent of the colonies operated by hobby and part-time beekeepers will go out of production due to the combination of low yields, management problems, shortage of apiary locations, and restrictive legislation.

The estimated 828,000 colonies of honey bees operated by hobby and part-time beekeepers in the 11 States included in Scenario I (table 1) produced an annual average of 41.4 pounds of honey and 0.70 pound of beeswax per colony, 1975-79. These colony numbers and yields were used to estimate the various losses.

If 50 percent of the noncommercial colonies go out of production, the reduction in beeswax and honey production from the colonies out of production totals $11.2 million (table 2). The value of a 30-percent decline in honey and beeswax production by the remaining colonies is $10.8 million.

If 80 percent of noncommercial colonies go out of production, the value of lost honey and beeswax produc-

**Table 2—Scenario I:   Estimated losses resulting from reduced honey and beeswax production in the 11 States assumed to be permanently colonized by the Africanized honey bee**

---

*Effect of 50 to 80 percent of the noncommercial colonies going out of production*

| 50 percent | 80 percent |
|---|---|
| Honey: (828,000 colonies) (0.5) (41.4 pounds per colony)<br>= 17,139,600 pounds<br>@ $0.62 = $10,626,552.00 | Honey: (828,000 colonies) (0.8) (41.4 pounds per colony)<br>= 27,423,360 pounds<br>@ $0.62 = $17,002,483 |
| Beeswax: (828,000 colonies) (0.5) (0.7 pound per colony)<br>= 289,800 pounds<br>@ $1.91 = $553,518.00 | Beeswax: (828,000 colonies) (0.8) (0.7 pound per colony)<br>= 463,680 pounds<br>@ $1.91 = $885,628.80 |
| Subtotal = $11,180,070.00 | Subtotal = $17,888,111.80 |

*Effect of a 30-percent decline in honey and beeswax yields from the remaining colonies*

| | |
|---|---|
| Remaining colonies total 1,337,000: 923,000 commercial colonies plus 50 percent of the 828,000 noncommercial colonies. | Remaining colonies total 1,088,660: 923,000 commercial colonies plus 20 percent of the 828,000 noncommercial colonies. |
| Honey: (1,337,000 colonies) (0.3) (41.4 pounds per colony)<br>= 16,605,540 pounds<br>@ $0.62 = $10,295,434.00 | Honey: (1,088,600 colonies) (0.3) (41.4 pounds per colony)<br>= 13,520,412 pounds<br>@ $0.62 = $8,382,655.40 |
| Beeswax: (1,337,000 colonies) (0.3) (0.7 pound per colony)<br>= 280,770 pounds<br>@ $1.91 = $536,270.70 | Beeswax: (1,088,600 colonies) (0.3) (0.7 pound per colony)<br>= 228,606 pounds<br>@ $1.91 = $436,637.46 |
| Subtotal = $10,831,704.70 | Subtotal = $8,819,292.86 |
| Total = $22,011,774.70 | Total = $26,707,404.66 |

---

Note: Production figures (41.4 pounds of honey per colony and 0.7 pound of beeswax per colony) reflect 1975–79 annual averages for 11 States affected by Scenario I (see table 1).

tion totals $17.9 million. The value of a 30-percent decline in honey and beeswax production by the remaining colonies is $8.8 million.

The combined economic effects of the reduction in honey and beeswax production from colonies going out of production and the decline in honey and beeswax yields from the remaining colonies ranges from $22 million if 50 percent of noncommercial colonies go out of production to $26.7 million if 80 percent of noncommercial colonies go out of production.

## Migratory Beekeeping

The 11 States in Scenario I include the primary wintering areas for migratory beekeepers. Calfornia, Florida, and Texas are the most important States with respect to the number of colonies overwintered. However, accurate, published statistics are not available on the number of colonies overwintered in the Southern States. Information provided by State apiary inspectors and other knowledgeable persons indicates that ap-

proximately 500,000 colonies are moved to the 11 States each winter. Each colony is divided into two or more colonies or nuclei during the winter and spring.

If bee shipments from States colonized by the AHB are quarantined, migratory beekeepers would have to adjust by overwintering a portion of their colonies in the North and splitting those colonies in the spring. The economic impacts would include the extra cost of overwintering colonies in the north plus the cost of feeding the splits during the spring. The economic effects are estimated using these assumptions:

1. Approximately 500,000 colonies are now moved to the 11 States for the winter.

2. On the average, each migrated colony is split in the South, and 1 million colonies are moved north in the spring.

3. With a quarantine on bee shipments from the 11 infested States, northern beekeepers will ar-

range to have 1 million colonies ready for the summer by overwintering colonies and dividing half of those colonies in the spring.

4. The following management plan will be used:
   - In the fall, all honey would be removed from colonies to be overwintered and sugar syrup would be fed for winter food.
   - Twenty percent of the colonies will die during the winter. Half the overwintered colonies will be divided in the spring.
   - These splits will be fed sugar syrup and pollen supplement to stimulate colony buildup to prepare them for the honey flow.
   - Fall feeding will average 45 pounds (dry weight) of sugar syrup. Splits will be fed 8 pounds of sugar syrup (dry weight) and 2 pounds of pollen supplement in the spring.

5. Sugar prices average $0.25 per pound on a dry weight basis (either granulated sugar or high fructose corn syrup), and a commercially prepared pollen supplement is used that costs $2 per pound.

Based on a 20-percent winter loss and dividing half of the overwintered colonies, the number of colonies ready for the summer honey flow can be derived from the equation

$$C_s = C_w(0.8)(1.5) \tag{1}$$

where: $C_s$ = desired number of colonies for summer

$C_w$ = number of colonies prepared for overwintering

0.8 = proportion of colonies that survive the winter (20-percent winter loss)

1.5 = the increase in total numbers after splitting half of the successfully overwintered colonies.

To get 1 million colonies for summer under this management plan, the number of colonies prepared for winter is solved by rearranging (1):

$$C_w = \frac{C_s}{(0.8)\,(1.5)} = \frac{C_s}{1.2} \tag{2}$$

and solving by substitution:

$$C_w = \frac{C_s}{1.2} = \frac{1,000,000}{1.2} = 833,333.$$

The cost of overwintering colonies is calculated: (833,333 colonies) (45 pounds sugar per colony) = 37,499,985 pounds @ $0.25 = $9,374,996.

Assuming a 20-percent winter loss, there will be about 666,000 live colonies in the spring (833,333 × 0.8 = 666,666). Half of these colonies (333,333) will be divided[7], the other half allowed to build up normally for the honey flow. The cost of feeding the splits in the spring is calculated:

Sugar:
(666,666 splits) (8 pounds per split) = 5,333,328 pounds @ $0.25 = $1,333,332

Pollen supplement:
(666,666 splits) (2 pounds per split) = 1,333,332 pounds @ $2.00 = $2,666,664

The total feed cost for overwintering colonies and making spring splits is about $13.3 million (table 3). No labor cost is included for making the splits because the same work is done, whether in the South or North. The added labor cost for fall and spring feeding is assumed to about equal the cost of loading and moving colonies south for the winter, so these costs are assumed to cancel each other out.

**Pollination**

No reliable statistics are available on the total number of bee colonies rented for pollination, the acreage of crops pollinated for a fee, or the revenues received. In the 11 States included in Scenario I, the almond crop probably generates more income from pollination fees than any other single crop. In recent years, approximately 150,000 to 200,000 colonies have been moved to California each year to pollinate almonds. A quarantine on bee shipments from the 11 AHB-colonized States would eliminate this pollination activity. Assuming half of these colonies are moved to California from outside the 11 AHB-colonized States, a quarantine on bee shipments from the AHB-area would reduce bees rented for almond pollination by 75,000 to 100,000 colonies. Beekeepers received about $18 per colony for almond pollination in recent years. Assuming 75,000 colonies are affected by the quarantine, beekeepers would suffer a revenue loss of $1.4 million annually (table 3).

---

[7]Splits are made from 333,555 colonies, thus the resulting number of splits is 667,110, twice the number of colonies.

Research on the economic effects on California almond growers and beekeepers caused by pesticide damage to bee colonies indicates almond growers lost $35-$107 per colony killed during pollination (38). This economic loss resulted from reduced almond yields caused by inadequate pollination. Using the lower value of this estimate ($35 per colony), almond growers could suffer a revenue loss of $2.6 million if 75,000 colonies of bees were not available to pollinate almond orchards because of quarantine on bee shipments (table 3).

## Total Losses

The total annual loss to the beekeeping industry and almond growers for Scenario I is about $54-58 million annually, with 50 and 80 percent of the noncommercial colonies going out of production, respectively (table 3). About 45 percent of the impact is from reduced honey and beeswax production in the AHB-colonized States. The loss of migratory beekeeping ($13.4 million) is about 24 percent of the total, the loss to the queen and package bee industry ($14.4 million) is about 25 percent, and the loss to almond pollination ($4 million) about 8 percent.

# Scenario II

Scenario II is based on the assumption that the AHB will colonize the same area as in Scenerio I, the area that has at least 240 frost-free days annually (fig. 3) and includes parts of 11 States. Thus the colony numbers, production, and revenues of the beekeeping industry are the same as described for Scenario I. However, the AHB is assumed to have lost its excessive stinging behavior but to have kept its other objectionable traits.

## Queen and Package Bee Production

Although the AHB is assumed to have lost its aggressive behavior, the retention of other objectionable traits is assumed to be sufficient grounds to maintain a quarantine on bee shipments from the 11 affected States. Thus the losses to the queen and package industry are the same as those estimated for Scenario I, $14.4 million annually (table 3).

## Honey and Beeswax Production

The AHB behavior assumed for Scenario II implies that the AHB will pose less of a problem to hobby and part-time beekeepers. Thus the losses resulting from changes in honey and beeswax production are moderate compared with the assumptions presented in the discussion of Scenario I: 20 to 40 percent of the colonies operated by hobby and part-time beekeepers in

the 11 affected States will go out of production, and honey and beeswax yields from the remaining colonies will decline by 30 percent. The bee colony numbers, honey and beeswax yields, and prices are the same as assumed for Scenario I.

If 20 percent of the noncommercial colonies go out of production, the value of the lost beeswax and honey production is about $4.5 million annually. The value of a 30-percent decline in honey and beeswax yields from the remaining colonies is about $12.8 million annually (table 4).

## Table 3—Estimated economic affects of a permanent African honey bee infestation in the United States: Four scenarios

| Bee industry sector | Scenario I[1] | Scenario II[2] | Scenario III[3] | Scenario IV[3] |
|---|---|---|---|---|
| | Million dollars | | | |
| Queen and package bees | 14.4 | 14.4 | 7.2 | 7.2 |
| Honey and beeswax:[4] | | | | |
| Colonies out of production | 11.2-17.9 | 4.5-8.9 | 6.3-10.1 | 2.5-5.0 |
| Yield decline | 10.8-8.8 | 12.8-11.5 | 6.3-5.1 | 7.4-6.6 |
| Total | 22.0-26.7 | 17.3-20.4 | 12.6-15.2 | 9.9-11.7 |
| Migratory beekeeping | 13.3 | 13.3 | 8.7 | 8.7 |
| Pollination:[5] | | | | |
| Beekeeper | 1.4 | 1.4 | — | — |
| Grower | 2.6 | 2.6 | — | — |
| Total losses | 53.8-58.5 | 49.0-52.1 | 28.5-31.1 | 25.8-27.6 |

— = Not applicable.
Note: Columns may not add due to rounding.
[1]The area assumed to be colonized by the AHB is in parts of 11 States with at least 240 frost-free days annually. Honey bee behavior is assumed to be typical of Africanized honey bees in South America.
[2]The area assumed to be colonized by the AHB is in parts of 11 States with at least 240 frost-free days annually. Honey bee behavior is assumed to be typical of Africanized honey bees in South America, except without excessive stinging.
[3]The area assumed to be colonized by the AHB is those States south of, or intersected by, latitude 32° North. For Scenario III, honey bee behavior is assumed to be typical of Africanized honey bees in South America. Scenario IV assumes typical Africanized bee behavior except without excessive stinging behavior.
[4]Reductions in honey and beeswax production are valued at 1981 U.S. season-average prices: honey, $0.62 per pound; beeswax, $1.91 per pound.
[5]Economic impact estimated only for almonds. Because no almonds are grown in States included in Scenario III and Scenario IV, no estimates of the impacts on pollination were made for those scenarios.

If 40 percent of the noncommercial colonies go out of production, the value of the lost honey and beeswax from colonies out of production is about $8.9 million annually. The value of a 30-percent decline in honey and beeswax yields from the remaining colonies is about $11.5 million annually.

## Migratory Beekeeping

The losses to migratory beekeepers will be about $13.3 million annually, the same as estimated for Scenario I (table 3).

## Pollination

The annual economic losses to almond producers and beekeepers who rent bees to pollinate almonds are $2.6 and $1.4 million, respectively, the same as estimated for Scenario I.

## Total Losses

The total losses from a Scenario II infestation range from $49.0-$52.1 million annually (table 3). Losses to

queen and package bee producers are $14.4 million annually, about 28 percent of the total. Losses due to reduced honey and beeswax production are $17.3-$20.4 million annually, about 35 percent of the total. Losses to migratory beekeepers are about $13.3 million annually, and losses to almond growers and beekeepers who rent bees to pollinate almonds total $4.0 million annually.

# Scenario III

Scenario III assumes the AHB will colonize the area south of latitude 32° North excluding the very small portions of New Mexico and Arizona below latitude 32° North (see fig. 3). The AHB is assumed to exhibit typical AHB behavior, as described earlier in the Research Methods and Assumptions section.

## Queen and Package Bee Production

Although no current, published statistics are available for the queen and package bee industry, surveys indicate roughly half the queen and package industry is in California and half is in the Southern States (34). A

**Table 4—Scenario II: Estimated losses resulting from reduced honey and beeswax production in the 11 States assumed to be permanently colonized by the Africanized honey bee**

*Effect of 20 to 40 percent of the noncommercial colonies going out of production*

| 20 percent | 40 percent |
|---|---|
| Honey: (828,000 colonies) (0.2) (41.4 pounds per colony) = 6,855,840 pounds @ $0.62 = $4,250,620.80 | Honey: (828,000 colonies) (0.4) (41.4 pounds per colony) = 13,711,680 pounds @ $0.62 = $8,501,241.60 |
| Beeswax: (828,000 colonies) (0.2) (0.7 pound per colony) = 115,920 pounds @ $1.91 = $221,047.20 | Beeswax: (828,000 colonies) (0.4) (0.7 pound per colony) = 231,840 pounds @ $1.91 = $442,814.40 |
| Subtotal = $4,472,028.90 | Subtotal = $8,944,056.00 |

*Effect of a 30-percent decline in honey and beeswax yields from the remaining colonies*

| | |
|---|---|
| Remaining colonies total 1,585,400: 923,000 commercial colonies plus 80 percent of the 828,000 noncommercial colonies. | Remaining colonies total 1,419,800: 923,000 commercial colonies plus 60 percent of the 828,000 noncommercial colonies. |
| Honey: (1,585,400 colonies) (0.3) (41.4 pounds per colony) = 19,690,668 pounds @ $0.62 = $12,208,214.00 | Honey: (1,419,800 colonies) (0.3) (41.4 pounds per colony) = 17,633,916 pounds @ $0.62 = $10,933.027.92 |
| Beeswax: (1,585,400 colonies) (0.3) (0.7 pound per colony) = 332,293 pounds @ $1.91 = $635,903.94 | Beeswax: (1,419,800 colonies) (0.3) (0.7 pound per colony) = 298,158 pounds @ $1.91 = $569,481.78 |
| Subtotal = $12,844,117.94 | Subtotal = $11,502,509.70 |
| Total = $17,316,146.84 | Total = $20,446,565.70 |

Note: Production figures (41.4 pounds of honey per colony and 0.7 pound of beeswax per colony) reflect 1975-79 annual averages for 11 States affected by Scenario II (see table 1).

conservative estimate that 1 million queens and 500,000 packages are produced annually in the United States suggests that 500,000 queens and 250,000 packages are produced in the Southern States. An estimated 90 percent of the packages and queens from Southern States are produced in Texas, Louisiana, Mississippi, Alabama, Georgia, and Florida. Based on these assumptions, a quarantine on bee shipments from these States would result in the loss of revenues, calculated as follows:

> Queens: (500,000)(0.9) = 450,000 queens
> @$6.00 = $2,700,000
> Packages: (250,000)(0.9) = 225,000 packages
> @$20.00 = $4,500,000

Thus, the total loss for the queen and package industry is about $7.2 million annually (table 3).

## Honey and Beeswax Production

About 850,000 colonies of bees are kept in the six States included in Scenario III. Commercial operators run about 460,000 colonies, and part-time and hobby beekeepers operate about 390,000 colonies (table 5). At 1981 prices, the values of the 1975-79 average honey and beeswax production from these colonies are $26 million and $1.2 million, respectively.

Because the AHB behavior assumed for Scenario III is the same as for Scenario I, the author assumed that honey and beeswax production will be affected in the same ways. The following data were used to estimate the economic losses:

1. Hobby and part-time beekeepers currently operate 393,000 colonies and commercial beekeepers operate 457,000 colonies in the affected area.
2. The average honey yield is now 49.2 pounds per colony, and the average beeswax yield is 0.77 pound per colony.
3. 1981 U.S. season-average prices of $0.62 per pound for honey and $1.91 per pound for beeswax.

If 50 percent of the noncommercial colonies go out of production, the value of lost beeswax and honey production from the colonies out of production will total $6.3 million. The value of a 30-percent decline in honey and beeswax yields from the remaining colonies is $6.3 million (table 6).

If 80 percent of the noncommercial colonies go out of production, the value of lost honey and beeswax production from the colonies out of production is about $10.1 million. The value of a 30-percent decline in honey

and beeswax yields from the remaining colonies is about $5.1 million.

The combined economic effects of the reduction in honey and beeswax production from colonies going out of production and the decline in honey and beeswax yields from the remaining colonies range from about $12.6 million (50 percent of the noncommercial colonies out of production) to about $15.2 million (80 percent of the noncommercial colonies out of production).

## Migratory Beekeeping

Although published statistics are not available on migratory bee movements, State apiary inspectors and others familiar with the industry estimate about 325,000 colonies are moved to the six States each winter. A quarantine on bee shipments from the six States included in Scenario III will require migratory beekeepers to alter their operations to maintain the same number of colonies operated for honey and beeswax production. The economic impact on migratory beekeepers is estimated using the assumption beekeepers will respond to a quarantine by overwintering colonies and making splits in the spring. The assumptions regarding fall feeding, winter loss, spring feeding, and feed costs are the same as described for Scenario I.

Assuming that beekeepers currently move 325,000 colonies south in the fall, split them all during the winter, and move 650,000 colonies north in the spring, beekeepers will need to provide 650,000 colonies for the

**Table 5—Scenarios III and IV: Bee colonies and honey production in affected States, 1975–79 average**

| State | Number of colonies[1] | | | Honey production | |
|---|---|---|---|---|---|
| | Hobby/ part-time | Commercial[2] | Total | Per colony | Total |
| | *-------1,000 colonies--------* | | | *Pounds* | *1,000 pounds* |
| Alabama | 23 | 23 | 46 | 21.0 | 966 |
| Florida | 180 | 180 | 360 | 66.0 | 23,634 |
| Georgia | 40 | 115 | 155 | 27.0 | 4,264 |
| Louisiana | 22 | 12 | 34 | 37.0 | 1,260 |
| Mississippi | 28 | 27 | 55 | 26.0 | 1,410 |
| Texas | 100 | 100 | 200 | 52.0 | 10,284 |
| Total | 393 | 457 | 850 | 49.2[3] | 41,818 |

[1]Includes colonies operated for honey production. Does not include colonies used for package bee and queen production.
[2]Includes colonies in beekeeping operations with more than 300 colonies. The number of commercial colonies in Alabama, Louisiana, and Mississippi were derived from USDA estimates of total colony numbers.
[3]Average production per colony in affected States.
Source: (*45, 46, 47*).

northern honey flow. Assuming a 20-percent winter loss, splitting half of the live colonies in the spring, and a requirement of 650,000 colonies for the summer honey flow, about 542,000 colonies would have to be prepared for winter.[8] From the 433,333 colonies that live through the winter (541,667 x 0.8 = 433,333), half will be split in the spring. Thus, 650,000 colonies will be ready for the honey flow (433,333 splits plus 216,666 colonies not split totals 649,999 colonies).

The economic effect is the sum of the fall feeding costs and the spring feedings costs for the splits. Using the assumptions developed in Scenario I, the loss is calculated as follows:

Fall feeding (sugar):
(541,666 colonies) (45 pounds per colony) = 24,374,970 pounds @$0.25 = $6,093,742.50

[8]This is computed as described for migratory beekeeping in Scenario I:

$$C_w = \frac{C_s}{1.2}, \text{ and by substitution, } C_w = \frac{650,000}{1.2} = 541,667.$$

Spring feeding:
Sugar—
(433,333 splits) (8 pounds per split) = 3,466,664 pounds @$0.25 = $866,666.00
Pollen supplement—
(433,333 splits) (2 pounds per split) = 866,666 pounds @$2.00 = $1,733,332.00

The total cost is about $8.7 million: $6.1 million for fall feeding, $2.6 million for spring feeding.

## Pollination

Published statistics are not available on the number of colonies pollinating particular crops in the six States, nor has research been published reporting the economic effects on crop producers in this area from reduced pollination due to bee kills as described for both Scenarios I and II. Because of this lack of data, no attempt was made to measure the economic effects that might occur.

**Table 6—Scenario III:   Estimated losses resulting from reduced honey and beeswax production in the six States assumed to be permanently colonized by the Africanized honey bee**

*Effect of 50 to 80 percent of the noncommercial colonies going out of production*

| 50 percent | 80 percent |
|---|---|
| Honey: (393,000 colonies) (0.5) (49.2 pounds per colony)<br>= 9,667,800 pounds<br>@ $0.62 = $5,994,036.00 | Honey: (393,000 colonies) (0.8) (49.2 pounds per colony)<br>= 15,468,480 pounds<br>@ $0.62 = $9,590,457.60 |
| Beeswax: (393,000 colonies) (0.5) (0.77 pound per colony)<br>= 151,305 pounds<br>@ $1.91 = $288,992.55 | Beeswax: (393,000 colonies) (0.8) (0.77 pound per colony)<br>= 242,088 pounds<br>@$1.91 = $462,388.08 |
| Subtotal = $6,283,028.55 | Subtotal = $10,052,845.68 |

*Effect of a 30-percent decline in honey and beeswax yields from the remaining colonies*

| | |
|---|---|
| Remaining colonies total 653,500: 457,000 commercial colonies plus 50 percent of the 393,000 noncommercial colonies. | Remaining colonies total 535,600: 457,000 commercial colonies plus 20 percent of the 393,000 noncommercial colonies. |
| Honey: (653,500 colonies) (0.3) (49.2 pounds per colony)<br>= 9,645,660 pounds<br>@ $0.62 = $5,980,309.20 | Honey: (535,600 colonies) (0.3) (49.2 pounds per colony)<br>= 7,905,456 pounds<br>@ $0.62 = $4,901,382.70 |
| Beeswax: (653,500 colonies) (0.3) (0.77 pound per colony)<br>= 150,958.5 pounds<br>@ $1.91 = $288,330.73 | Beeswax: (535,600 colonies) (0.3) (0.77 pound per colony)<br>= 123,723.60 pounds<br>@ $1.91 = $236,312.07 |
| Subtotal = $6,268,639.93 | Subtotal = $5,137,694.77 |
| Total = $12,551,668.48 | Total = $15,190,540.45 |

Note: Production figures (49.2 pounds of honey per colony and 0.77 pound of beeswax per colony) reflect 1975-79 annual average for six States affected by Scenario III (see table 5).

## Total Losses

The sum of the losses estimated for Scenario III ranges from $28.5-$31.1 million annually (table 3). The combined loss to the queen and package industry and to migratory beekeepers totals about $16 million, and the reduction in honey and beeswax production totals about $13-$15 million.

## Scenario IV

Scenario IV is based on the assumption that the AHB will colonize the same area as in Scenario III, the area south of latitude 32° North except for portions of Arizona and New Mexico (fig. 3). Thus, the colony numbers, production, and revenues of the beekeeping industry are the same as described for Scenario III. Unlike Scenario III, the AHB is assumed to have lost its excessive stinging behavior, but to have kept its other objectionable traits.

### Queen and Package Bee Production

Although the AHB is assumed to have losts its aggressive behavior, the retention of other objectionable traits should be sufficient grounds to maintain a quarantine on bee shipments from the six affected States. Thus, the annual loss to the queen and package industry in these States is $7.2 million, the same as calculated for Scenario III.

### Honey and Beeswax Production

Because the AHB is assumed to have lost its excessive stinging behavior, the restrictive zoning and management problems due to stinging should have less effect than was assumed for Scenarios I and III. The losses resulting from changes in honey and beeswax production are estimated based on the following assumptions:

1. Twenty to 40 percent of the colonies operated by hobby and part-time beekeepers in the six affected States will go out of production.

2. Honey and beeswax yields from the remaining colonies will decline by 30 percent.

3. Colony numbers, honey and beeswax yields, and prices are the same as assumed for Scenario III.

Table 7—Scenario IV: Estimated losses resulting from reduced honey and beeswax production in the six States assumed to be permanently colonized by the Africanized honey bee

*Effect of 20 to 40 percent of the noncommercial colonies going out of production*

| 20 percent | 40 percent |
|---|---|
| Honey: (393,000 colonies) (0.2) (49.2 pounds per colony) = 3,867,120 pounds @ $0.62 = $2,397,614.40 | Honey: (393,000 colonies) (0.4) (49.2 pounds per colony) = 7,734,240 pounds @ $0.62 = $4,795,228.80 |
| Beeswax: (393,000 colonies) (0.2) (0.77 pound per colony) = 60,522 pounds @ $1.91 = $115,597.02 | Beeswax: (393,000 colonies) (0.4) (0.77 pound per colony) = 121,044 pounds @ $1.91 = $231,194.04 |
| Subtotal = $2,513,211.42 | Subtotal = $5,026,422.84 |

*Effect of a 30-percent decline in honey and beeswax yields from the remaining colonies*

| | |
|---|---|
| Remaining colonies total 771,400: 457,000 commercial colonies plus 80 percent of the 393,000 noncommercial colonies. | Remaining colonies total 692,800: 457,000 commercial colonies plus 60 percent of the 393,000 noncommercial colonies. |
| Honey: (771,400 colonies) (0.3) (49.2 pounds per colony) = 11,385,864 pounds @ $0.62 = $7,059,235.60 | Honey: (692,800 colonies) (0.3) (49.2 pounds per colony) = 10,225,728 pounds @ $0.62 = $6,339,951.30 |
| Beeswax: (771,400 colonies) (0.3) (0.77 pound per colony) = 178,193.4 pounds @ $1.91 = $340,349.39 | Beeswax: (692,800 colonies) (0.3) (0.77 pound per colony) = 160,036.8 pounds @ $1.91 = $305,670.28 |
| Subtotal = $7,399,584.99 | Subtotal = $6,645,621.58 |
| Total = $9,912,796.41 | Total = $11,672,044.42 |

Note: Production figures (49.2 pounds of honey per colony and 0.77 pound of beeswax per colony) reflect 1975-79 annual average for six States affected by Scenario III (see table 5).

If 20 percent of the noncommercial colonies go out of production, the value of lost beeswax and honey production from the colonies out of production is about $2.5 million (table 7). The value of a 30-percent decline in honey and beeswax yields from the remaining colonies is about $7.4 million.

If 40 percent of the noncommercial colonies go out of production, the value of lost honey and beeswax production is about $5 million. The value of a 30-percent decline in honey and beeswax yields from the remaining colonies is about $6.6 million.

The combined economic effects of the reduction in honey and beeswax production from colonies' going out of production and the decline in honey and beeswax yields from the remaining colonies ranges from about $9.9 million (20 percent of the noncommercial colonies out of production) to about $11.7 million (40 percent of the noncommercial colonies out of production.)

### Migratory Beekeeping

If a quarantine is imposed on live bee shipments from the AHB-colonized area, migratory beekeepers will face the same problems as described for Scenario II. The loss to migratory beekeepers in the six affected States will be about $8.7 million annually, as calculated for Scenario III. Fall feed costs are estimated to be $6.1 million and spring feed costs for splits are estimated to be $2.6 million, totaling $8.7 million.

### Pollination

No losses are estimated for the same reasons listed in the pollination section of Scenario III.

### Total Losses

The losses from a Scenario IV AHB infestion range from $25.8-$27.6 million annually (table 3). The annual costs to migratory beekeeping and losses to the queen and package bee industry are about $8.7 million and $7.2 million, respectively. Losses from reductions in honey and beeswax productions are about $10-$12 million annually, about 40 percent of the total loss.

## AHB Infestation and the Future of Commercial Beekeeping

The discussions of each of the preceding scenarios assumed that there would be a 30-percent reduction in honey yields in AHB-infested States (tables 1, 3, 5).

Such a yield reduction could be especially critical for commercial beekeepers who must at least cover operating costs to stay in business.

Using 1971-75 financial records for 118 commercial firms, and updating the data to 1981 dollars, several conclusions can be drawn about the possible effects of a 30-percent reduction in honey yields (52). The sample includes firms in the States which might be infested by the AHB; these States account for about 95 percent of the commercial honey production in the United States.

After adjusting the data to 1981 prices, the 118 firms would have earned an estimated pretax net profit of $1.5 million. However, had the beekeepers lost 30 percent of their honey yield they would have experienced an aggregate net loss of $1.76 million. In order to break even—that is, raise honey prices to offset the yield reduction and neither make nor lose money—the price of honey would have to reach 76.6 cents per pound. That is about 21 percent higher than 1981 U.S average price and about twice the 1981 price on the world market. These data and the methodology used in arriving at them are discussed in greater detail in appendix 2 of this report.

A firm experiencing reduced output of its primary product because of factors beyond its control (such as beekeeping firms whose honey production may decline because of the AHB) must either reduce costs or increase revenue to maintain profits. Such firms have essentially five alternatives:

1. Decrease production costs,
2. Raise the price of their primary product,
3. Raise the price of their secondary products and services,
4. Increase the output of secondary products and services, or
5. Develop new products and services.

These do not seem to be realistic alternatives for the beekeeping industry if honey yields decline due to the various effects of the AHB.

Reducing production costs is possible, but because of the basic biological nature of the work, few innovations have been made for mechanizing the basic tasks of beekeeping. Except for using forklifts to load beehives, gas-powered blowers to aid in harvesting the honey crop, and more automated honey-extracting equipment, few advances have been made that can significantly reduce costs (1). It is unlikely beekeepers could reduce costs sufficiently to maintain profitability if yields decline.

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Like producers of many agricultural products, most honey producers are price takers, not price setters. If honey yields decline due to the AHB, domestic honey prices are unlikely to increase to the levels necessary to maintain profitability or to simply break even as long as imported honey is available to maintain current supplies. Even if honey prices were to increase to the necessary levels, it's doubtful that the quantity demanded would remain constant if honey prices increased sharply.

The decision to produce other items or services besides honey and beeswax is determined partly by the price and production of honey. If honey prices are high or if production is high, there is a high opportunity cost for producing alternative products or providing pollination services. If commercial beekeepers' honey yields decline in the area colonized by the AHB, the opportunity cost of producing other items or providing pollination services will decline. Thus, more beekeepers will be inclined to produce alternative products and to provide pollination services. In this case, with larger supplies of alternative products such as pollen, propolis, and bee venom, and with more beekeepers willing to provide pollination services, prices would probably decline for these products and services. Thus, beekeepers will probably not be able to increase the prices they charge for these goods and services; in reality, prices will probably decline because of increased supplies. As a result of the decline in honey production, the market price for pollination services and their alternative products may actually decline, further reducing revenues and increasing financial losses.

The potential items a beekeeping firm can produce include honey and beeswax, package bees, honey bee queens, pollen, propolis, royal jelly, and bee venom. Pollination services can also be offered. Producing queens and package bees in lieu of, or in addition to, producing honey is not feasible because it is assumed that shipments of live bees out of the States colonized by the AHB will be prohibited. The market potential for pollen, propolis, royal jelly, and bee venom is limited and certainly could not support the entire beekeeping industry.

The final conclusion is that the U.S. commercial beekeeping industry has no realistic alternatives to relying on honey production as the primary economic base of their industry. Without adequate prices and levels of honey production, a large proportion of the commercial beekeepers in the affected States may have no alternative to going out of business if yields decline as assumed. If these commercial beekeepers go out of business, U.S. honey production would be reduced by 13-22 percent and the provision of pollination services could be severely disrupted in some parts of the United States.

## Consumer Costs

Honey consumption in the United States averaged about 240 million pounds annually, 1970-80 (48). During this time domestic production averaged 209 million pounds, and imported honey met the shortfall between consumption and domestic production. If the AHB colonizes the United States, potential reductions in honey production will range from 15-41 million pounds, depending on the scenario (tables 2, 4, 6, and 7). This represents about 7 to 20 percent of average U.S. production, 1975-79. While American honey production averaged about 209 million pounds annually during 1970-80, production varied by as much as 51 million pounds from year to year. Thus, potential losses from the AHB are within normal variations in U.S. honey production.

Domestic honey prices have risen steadily since 1970, but the real domestic price of honey is not statistically correlated with domestic production (45).[9] That is, fluctuations in domestic honey production have not had a significant effect on U.S. honey prices. This suggests that changes in U.S. honey production due to effects of the AHB would not have much effect on U.S. honey prices.

Additional evidence that the estimated reductions in production would not raise honey prices is provided by the lack of price change in response to honey's being effectively taken off the market by the Commodity Credit Corporation (CCC). The CCC, an agency of the U.S. Department of Agriculture, takes possession of honey through the honey price support program. In the past 2 years, the CCC has acquired quantities of honey in excess of the reductions that could result from the AHB. Despite the large quantities of honey taken off the market, honey prices have not increased materially.

If imports remain available at their current levels, no reduction in available supplies for U.S. consumption would occur. Assuming no change in available supplies, no increase in the price of honey (other than price changes that could occur for other reasons such as changes in consumer tastes, national income, or population) would be anticipated. This conclusion is based on all other factors remaining constant.

A number of changes may occur that complicate the picture. The estimated losses resulting from an AHB in-

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[9]The real price of honey is defined as the nominal price deflated (corrected for inflation) by the Consumer Price Index.

festation are based on a number of assumptions, including that no commercial honey producers would go out of business. At current honey prices, a large proportion of the commercial honey producers in the States that could be colonized by the AHB would probably go out of business if honey yields decline by 30 percent as assumed for all four AHB scenarios (see app. 2). If this occurred, honey production would be reduced by twice the amount indicated in the basic economic effects presented in table 3.

The supply of imported honey could also be disrupted by the movement of the AHB into Central America and Mexico. Mexico is a major exporter of honey to the United States. If the Mexican beekeeping industry is affected as severely as the Venezuelan beekeeping industry was, Mexican honey production and exports would be severely reduced.[10] Five Central American countries that could also be affected by the AHB are among the 10 principal suppliers of imported honey to the United States (2).

In addition to potential reductions in Mexican honey production, Canadian honey production could be affected if early-season package bees and queens are not available from the United States. The Canadian beekeeping industry relies on the United States for package bees and queens to establish colonies in the early spring, replacing colonies that are either killed in the fall or die during the winter. By killing bee colonies in the fall, Canadian beekeepers are able to market substantially more honey than if they had to overwinter bee colonies. If the traditional early-season shipments of queen bees and package bees from the United States are reduced or eliminated, Canadian honey production could be reduced, hence the honey available for export would also be reduced.

A reduction in world honey production could result in a rise in the world price. Unfortunately, statistics and research on consumer demand for honey are not available to estimate the potential price effects from a reduction in world honey production.

Because of the number of crops that depend on or are benefited by bee pollination, consumer effects from reduced pollination services are potentially much higher than those from reduced honey production. An estimated $3.47 billion of fruits, nuts, and vegetables were

produced in 1980 that require or benefit from bee pollination (app. 1).

Apiculturists and agronomists have not ventured estimates of the yield reductions that could result from inadequate pollination due to AHB effects on beekeepers. However, the following example shows the potential magnitude of a 1-percent decrease in the production of the fruit, nut, and vegetable crops that benefit from bee pollination.

One measure of the relationship between price and quantity of a commodity is the price elasticity of demand ($E_p$) which measures the percentage change in quantity demanded in response to a given percentage change in price. A related measure of how quantity supplied affects price is the price flexibility ($F_p$), approximately defined as the inverse of the price elasticity:

$$F_p = \frac{1}{E_p}$$

The price flexibility is an estimate of the percentage price change that would result from a 1-percent change in quantity supplied (43).[11]

Farm-level price elasticities for fruits and vegetables range from $-0.095$ for lettuce to $-0.355$ for tomatoes to $-0.72$ for apples (12). The midpoint of these estimates is $-0.3855$, which nearly equals the estimated retail price elasticity of $-0.40$ for "other" canned fruits and vegetables. Given an average price elasticity of $-0.40$, the corresponding price flexibility is $-2.5$ (that is, $1/-0.40 = -2.50$). Based on these assumptions, a 1-percent decrease in the supply of fruits and vegetables would increase farm-level prices by about 2.5 percent.

Because price rises more than production declines (in percentage terms), consumers' total expenditure for the commodity increases when supply is reduced. The welfare of consumers is affected in two ways. First, consumers' welfare is reduced because they consume less of the commodity. Second, consumers pay more for the commodity, and thus (assuming income is constant) must consume less of all other goods and services;

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[10]An evaluation of the potential of the AHB on beekeeping in Mexico and Central America concluded that 80 to 90 percent of hobby beekeepers and 30 to 40 percent of commercial beekeepers would cease beekeeping unless technical assistance were available (55).

[11]The price flexibility is equal to the inverse of the price elasticity only when there are no substitutes for the commodity. In mathematical terms: $|F_p| \leq |1/E_p|$, or the inverse of the price elasticity is the upper bound of the price flexibility (43). For the problem in question where a broad range of fruits and nuts are aggregated, the number of substitutes is limited. In such a case, the inverse of the price elasticity is probably a reasonable estimate of the price flexibility.

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## Government Policies Pertaining to Honey

The U.S. honey price support program works in the following way: Honey producers can apply for a loan from the program, pledging their honey as collateral. The honey is valued at the support price which is computed based on "parity," or the costs and returns to beekeeping in a previous period or year. The producer then has two options: to sell the honey on the open market and repay the loan, or let the CCC take possession of the honey and have the loan forgiven. For a more complete discussion of the support program see *Beekeeping in the United States (22)*.

The apparent inconsistency of the U.S. Government's acquiring large quantities of honey while large quantities of honey are imported results from the disparity between the world honey price and the U.S. support price, and the comparatively low tariff imposed on imported honey by the United States. The U.S. support price, based on parity, is not related to the supply-and-demand forces that determine price on the open market. Because the CCC will acquire unlimited quantities of domestically produced honey (providing it meets minimum standards for quality and packaging) at the support price, American honey producers have no economic incentive to sell their honey for less than the support price. When supply-and-demand conditions at the world level create a price lower than the U.S. support price, many U.S. honey producers sell their honey to the highest bidder—usually the U.S. Govern-

ment—and U.S. honey packers buy lower priced imported honey.

The tariff on honey entering the United States is 1-2 cents per pound, depending on the trade status of the exporting country. By contrast, the European Community places a 26-percent ad valorem tax on imported honey, or about 10 cents per pound on honey sold at 40 cents per pound by the exporting country (51). Thus, compared to European countries, the U.S. tariff adds little to the retail price of honey, so imported honey can be very competitive on the basis of price. Price is an important factor influencing decisions of American honey packers, but consumer preference for lighter grades of honey is also a factor in the volume of honey imports.

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this is equivalent to a reduction in income. The sum of these two effects is referred to as the change in consumers' surplus (13).

The following equation provides a convenient approximation of the change in consumers' surplus resulting from changes in price and supply (6).

$$CS = \frac{[(P_1 - P_2)(Q_1 + Q_2)]}{2} \qquad (3)$$

where: $P_1$ = price in time period 1 ($T_1$)
$P_2$ = price in a later time period ($T_2$)
$Q_1$ = quantity supplied in $T_1$
$Q_2$ = quantity supplied in $T_2$
$CS$ = change in consumers' surplus

By treating the production of those fruits and vegetables valued at $3.471 billion in 1979 (see app. 1) as one unit of a product with a price of $3.471 billion, the change in consumers' surplus caused by a 1-percent decrease in supply and a 2.5-percent increase in price is computed as follows:[12]

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[12]Assuming price increased by 2.5 percent, the new value is $3.558 billion (3.471 x 1.025 = 3.558).

$$CS = \frac{(\$3.471 \text{ billion} - \$3.558 \text{ billion})(1.0 + 0.99)}{2}$$
$$= -\$86.57 \text{ million}$$

Thus, a 1-percent decline in production of the $3.471 billion of vegetables, fruits, and nuts produced in 1979 that rely on bee pollination would reduce consumers' welfare by about $87 million.

The potential consumer effect from a 1-percent decline in production of those crops directly attributed to bee pollination is 50 percent higher than the total losses to the entire beekeeping industry for the worst scenario (table 3). While this is only an example, it does not include the value of oilseed, fiber, seed, vegetable, and forage crops produced from bee-pollinated seed, and other secondary products. If supplies of these commodities are reduced, prices would increase and consumers' welfare would be further reduced.

## Conclusions

The annual losses estimated for the four scenarios of an AHB infestation in the southern parts of the United States present a serious threat to the financial health, and perhaps the existence, of the U.S. beekeeping in-

dustry. The U.S. beekeeping industry earns revenues of about $180 million annually: about $130 million from honey, $5 million from beeswax, $16 million from package bee and honey bee queens, and an estimated $30 million from pollination rentals.[13] The annual losses estimated for Scenario I are $54-$58 million, about 30-32 percent of the current total revenue. Annual losses for Scenario II are estimated at $49-$52 million, about 27-29 percent of current total revenue. Annual losses estimated for Scenario III are $28-$31 million, about 16-17 percent of current total revenue. Annual losses for Scenario IV are $26-$28 million, about 14-16 percent of total revenue.

The magnitude of these losses is substantial; unless research and technical aid to successfully reduce some of the potential problems posed by the AHB becomes available, many commercial and part-time beekeepers will go out of business, and many hobby beekeepers will quit beekeeping.

The current economics of beekeeping gives scant promise for either reducing production costs or increasing honey prices enough to maintain profitability. The prospect for a strong industry response to these problems is not good, given the industry's economic problems: large domestic surpluses of honey, a price support system that is under attack, a world honey price 30 percent lower than the U.S. price, continuing large supplies of imported honey, stagnant U.S. per capita consumption of honey, and declining acreages of good bee pasture.

A number of important potential effects were not considered. These include the effects on public health, labor problems working with the AHB, bee-disease management problems associated with large feral populations, effects on bee supply and equipment businesses, the value of equipment abandoned by hobby and part-time beekeepers, and the effect on other countries, such as Canada, whose beekeeping industries rely heavily on the United States for queens and package bees. The effect of summer intrusions of AHB populations into more northern areas each summer were also not considered.

Because the value of bee-pollinated commodities so far exceeds the value of bee products (honey, pollen, wax, package bees, and queens) even small reductions in the yields of bee-pollinated crops would have substantial effects. The AHB will affect beekeepers in the United States, but a number of professional apiculturists believe the effects on pollination will exceed the effect of the AHB on beekeepers by a considerable margin (27). In addition to the crop plants benefited by bee pollination, many noncrop plants that provide esthetic benefits, food and cover for wildlife, and erosion control are benefited by bee pollination (9). The production of these crop and noncrop plants could be impaired if bee populations decline, directly or indirectly, due to the AHB.

The conclusions that can be drawn from the estimated economic effects are somewhat limited due to the data constraints imposed on the study. The estimates are the results of an analysis that by necessity assumed away considerable detail and utilized proxy measures of some potential effects.

A major limiting factor is the lack of a coherent set of data on the AHB, from basic biology to management techniques for dealing with it in a commercial beekeeping setting. Questions regarding AHB behavior in temperate climates, its overwintering ability, its potential geographic range—all critical elements of an assessment of its potential effect on the United States—are unresolved. While considerable data and reports on the AHB have been published, a prominent researcher observed (27): "A frustrating aspect of the literature on the Brazilian honey bees has been the divergence of opinions and information presented."[14]

The lack of consistent, reliable data on the AHB is matched by the lack of reliable, current, published data on the U.S. beekeeping industry. There are no published statistics for pollination, migratory beekeeping, nuclei production, queen and package bee production, or any of the minor hive products such as pollen and bee venom. The last survey of the package and queen industry was done in 1969 (34). No official contingency plans were available to use in estimating the economic effects, so the possible actions had to be assumed.

Because the economic assessment was done without complete biologic or economic data, it relies heavily on assumption and expert opinion. The economic effects presented in this report are not predictions, but are rough estimates of what could happen based on a given set of circumstances.

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[13]Total revenue from pollination rentals based on financial data from commercial beekeeping firms (51).

[14]"Brazilian bees" in this quotation refers to Africanized honey bees.

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## Appendix I

## The Role of Bees in Crop Pollination

Pollination is the transfer of pollen (male reproductive cells) from the stamen of one flower to the pistil (female portion of the flower) of that or another flower. Fertilization is the fusion of male and female germ cells in the ovule of the flower. Self-pollination occurs when pollen is transferred to the pistil of the same flower. If that flower is self-fertile (capable of being fertilized by its own pollen) fertilization can occur. Self-fertile plants can be self-pollinating (not requiring an external agent to transfer the pollen) or may require an external agent, either physical or biological, to transfer the pollen. Other types of flowers are self-sterile and must be pollinated with pollen from another flower in order to be fertilized (23).

Bees are pollinators of more than 100 agricultural crops in the United States (24). Many vegetables do not need bees or pollination to produce a crop, but they are grown from bee-pollinated seed. Bee pollination is required to produce seeds of forage legumes such as clovers and alfalfa, which in turn are important to the production of meat and milk products. Oilseed crops such as cotton, sunflowers, soybeans, safflower, and rape benefit from bee pollination (23).

The economic benefits of pollination are not due solely to honey bees. Pollinating agents include wind and a wide variety of other insects including wasps, butterflies, moths, beetles, and flies. Despite the wide range of insects capable of pollinating crops, it is estimated that 80 percent of crop pollination is achieved by bees (24). A few species of wild bees have been more or less domesticated for man's use, but the honey bee is still the only pollinating insect that can be easily managed in sufficient numbers, moved at will, increased easily, provided year round, and that is able to pollinate a wide variety of crops.

### Economic Value to U.S Agriculture

Estimates of the economic value of bee pollination to U.S. agriculture range from $4.5 billion in 1952 (25), in excess of $1 billion in 1967 (23), to more than $8 billion in 1976 (51). However, none of these reports provides an itemization of the value by crop. Two recent research summaries provide estimates of the value of bee pollination to specific crops for 1979 (11) and 1980 (20). These estimates were derived from a summary of crops requiring or benefiting from bee pollination (23) and USDA estimates of the value of production of specific

crops (48). The value of U.S. crops that required or benefited from bee pollination, 1979-80, were estimated as follows:

|  | Bil. dol. |
| --- | --- |
| Fruits, nuts, and vegetables | 3.47-4.06[1] |
| Seeds and fiber | 1.63-2.54 |
| Total | 5.10-6.60 |

In addition, the value of crops derived from bee-pollinated seed were estimated as follows:

|  | Bil. dol. |
| --- | --- |
| Vegetables | 0.99-1.18 |
| Alfalfa hay | 4.40-4.98 |
| Cattle, calves, and milk[2] | 7.07-7.12 |
| Total | 12.46-13.28 |

Thus, the total value of bee pollination to U.S. agriculture, as estimated from these two studies, is about $17.6-$19.9 billion annually. Not included in these totals is the value of hay and forages derived from minor forage legumes such as clovers, lespedeza, and vetch. There are a number of minor vegetable and fruit crops, either dependent on or benefited by bee pollination, plus vegetable and fruit crops grown from bee-pollinated seed that are not included in these estimates because the value of production is not published in USDA's "Agricultural Statistics."

### Potential Effects of the Africanized Honey Bee on Pollination

Although the potential effect of the AHB on the pollination and hence production of these crops has not been estimated, several factors indicate the potential effects may be substantial. Much of the bee-pollinated vegetable seed and the vegetables grown from this seed are produced in areas where the AHB may become permanently established. Much of the fruit and nut production that benefits from bee pollination is also in the area that the AHB may colonize. Most pollination services for northern growers of bee-benefited crops are

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[1]The main difference between these totals is the inclusion of grapes and some citrus crops in the higher figure that are not included in the lower. The benefit of bee pollination to these crops is disputed and in some cases is difficult to aggregate due to varietal differences (23).

[2]Value of bee pollination is based on 10 percent of the value of cattle, calves, and milk production. This is based on the assumed contribution of alfalfa hay (derived from bee-pollinated seed) which accounts for about 60 percent of the U.S. hay crop. This is not meant to be a definitive assessment of the value of alfalfa hay to the production of meat and milk products; it is included to be indicative of the economic contribution.

provided by commercial beekeepers, many who currently move their operations to the South each year (51). A quarantine on live bee shipments from States colonized by the AHB could severely disrupt the current provision of pollination services to farmers in Northern States.

The aggressive characteristics of the AHB may deter farmers from growing crops that require bee pollination because of the risk and liability associated with having the bees on their farms. This may reduce beekeepers' income if pollination revenues decline, it may reduce production of some bee-pollinated crops (thus increasing the prices consumers will have to pay), and farmers may experience income losses if they shift to less intensive cropping patterns. In some areas of South America, AHB nests in orchards have interfered with harvest of tree crops. The potential exists for a similar situation in this country, especially on tree crops that are harvested by mechanically shaking the trees.

The large feral AHB populations in many areas have altered the populations of wild bees in the tropics (36). If a similar phenomenon occurs in the United States, pollination from wild bees may decrease if their populations decline. However, large AHB populations may benefit some crops if high AHB populations occur when those crops flower.

If the production of bee-pollinated seeds suffers due to the AHB, the spillover effects could include temporary reductions in vegetable and forage production if seed supplies are reduced. Reduced yields of seed crops could lower grower returns (all other factors constant) and additional acreage would have to be devoted to seed production to maintain current production. Reduced output of bee-pollinated crops could lead to higher prices for affected commodities. The effects could last for a considerable length of time because many of the bee-pollinated fruits and nuts are permanent crops, and production cannot be increased quickly because of the time required to plant and develop orchards. A number of researchers have speculated that the negative effects on pollination may greatly exceed the effect on the beekeeping industry (27).

## Effectiveness of Wild Pollinators

If the AHB disrupts the commercial beekeeping industry that currently provides most pollination services, U.S. agriculture may not be able to rely on wild bees and other pollinating agents to provide an adequate level of pollination.

The term "wild bees" refers to all bees except honey bees (Apis species). Feral honey bees are sometimes included in this category. There are about 5,000-6,000 species of wild bees in the United States and more than 30,000 species of wild bees worldwide (22). Less than 10 percent of the wild bee species in the United States have been studied. Furthermore, the information necessary to estimate the effect of individual wild bee species on the fruit and seed production of major crops is almost nonexistent (32). Because of the lack of research on wild bees, there is no accurate way to put a dollar value on wild bee pollination.

Wild bees are often quite numerous in undisturbed areas, and in certain situations are important pollinators of wild plants and cultivated crops. However, studies of wild bee pollination of cultivated crops have demonstrated that modern farming practices adversely affect wild bee populations, sometimes reducing their populations to the point that their contribution to the pollination of wild and cultivated plants is seriously reduced (17, 28).

Practices such as extensive monoculture, herbicide use that reduces the variety of plant species, and insecticide use all reduce the variety of plant and animal life in agro-ecosystems to the detriment of wild bee populations. Insecticides are particularly hard on wild bees because many wild bee species are smaller than honey bees and as a result are more susceptible to pesticides (15). Although most are not toxic to bees, herbicides eliminate important sources of nectar and pollen by killing wild vegetation. This reduces the carrying capacity of the bee pasture, affecting both wild bees and managed honey bees. This decline in turn reduces the early spring pollen and nectar flows important for building bee populations and often reduces late fall nectar flows. These declines in food supplies retard growth of bee populations in the spring and increase winter mortality by reducing the available food in the fall (19).

Drainage, burning, reductions in fence row areas and uncultivated border zones, and conversion of forest, brush, and pasture to croplands or urban and industrial uses reduce the habitat for wild bees. These activities reduce or eliminate the continuum of flowering plants during the growing season, thus reducing or altering the continuity of food sources for wild bees. In addition many of these activities eliminate nesting sites for wild bees. The net effect is to restrict the number and populations of wild bee species that can adapt to modern agro-ecosystems (21).

Studies of wild bee pollination of cultivated crops provide evidence of the effects of modern farming practices on wild bee populations. For example, melon, squash, and cucumber production is highly dependent

on bee pollination. As typical farming practices in the Southeast accelerate the destruction of nesting sites and eliminate the availability of nectar and pollen sources during the year, the dependence on honey bee pollination of these crops grows yearly (35). Wild bee visitations to Arizona cotton fields show very large fluctuations from week to week, month to month, and year to year (28). Many species were observed, but the total populations were not substantial as far as effecting cotton pollination. Also, wild bees in large cotton fields were rare; wild bees were commonly seen only in fields of less than 10 acres.

Pesticides can have important effects on pollination of crop and noncrop plants. The use of organophosphorus insecticides near blueberry fields in Canada decimated nearby wild bee populations (17). Following the reduction of wild bee populations, blueberry yields plummeted to near-failure levels. At the same time, significant reductions in the pollination and seed set of wild plants nearby were recorded. Wild bee populations in areas not sprayed suffered no such decline. Following the reduction of wild bee populations, blueberry growers had to rent honey bees to pollinate their blueberry fields to achieve economic yields. After the use of insecticides highly toxic to bees was curtailed, wild bee populations recovered, as did blueberry yields in fields not pollinated by honey bees. This provides a dramatic example of how inadequate pollination can occur if honey bees are not available to compensate for reduced populations of pollinators resulting from modern farming practices—or if honey bees are not available because the current provision of pollination services is disrupted by the AHB.

Some wild bee species are very effective pollinators of specific crops (3). However, they tend to be more food-specific than honey bees. Thus they are often less effi-

cient pollinators on a wide variety of crops than are honey bees. Research on tropical pollinators suggests that highly social bees are superior to less social or solitary bees in discovering and harvesting nectar and pollen. Furthermore, honey bees may be the ecological equivalent of many wild bee species from the standpoint of the pollination services provided by individual species (37).

These examples provide evidence that, except for a very few situations, wild bees and other wild pollinators are currently not capable of providing adequate pollination services in a modern agricultural setting. The decline of wild pollinators was noted in the early 1950's; many species abundant a decade earlier had succumbed to large-scale farming and modern agricultural techniques (3). Since then, populations of wild pollinators have probably been further reduced by land-use changes, intensive agriculture, and pesticide use.[3]

In the early 1940's, prior to much of the major increases in pesticide use and expanded use of monoculture, an assessment of the role of beekeeping in U.S. agriculture noted (44): "The chief supply of pollinators in the United States is maintained by the beekeeping industry...maintaining this industry in a healthy condition is essential to our agricultural economy because without adequate numbers of honey bees for pollination, the yields and quality of the many crops that either require or are benefited by insect pollination would be reduced." This statement is probably still true.

_____
[3]The populations of some species such as the alkalai bee (Nomia melanderi) and the leafcutter bee (Megachile rotunda) may have been increased by efforts to propagate these species for alfalfa seed production and by increased alfalfa acreage.

Robert McDowell

# Appendix 2
# The Effects of Reduced Honey Yields on the Profitability of Commercial Beekeeping: Methodology

The losses resulting from the reduction in honey and beeswax yields (table 3) assumed a 30-percent decline in yields from all colonies in the States assumed to be colonized by the AHB (tables 1 and 5). This yield decline would not be as critical to hobby and part-time beekeepers as to commercial operators who must at least cover operating costs to stay in business. One assumption implicit in calculating the losses is that the number of colonies operated by commercial beekeepers in the AHB-colonized States would remain constant (table 3). To determine the validity of this assumption, the effect of a 30-percent decline in honey and beeswax yields on the net profits of beekeeping firms was examined.

## Commercial Beekeeping in States Subject to AHB Colonization

In the 11 States assumed to be colonized by the AHB in Scenarios I and II, commercial beekeepers operate about 923,000 colonies that produced an annual average of about 46.6 million pounds of honey (1975-79) valued at $29.5 million at 1981 prices. In the six States assumed to be colonized by the AHB in Scenarios III and IV, commercial beekeepers operate about 457,000 colonies that produced about 27 million pounds of honey annually (1975-79) valued at $17.1 million at 1981 prices (46). Based on these figures, commercial beekeepers in the 11 States in Scenarios I and II produced about 22 percent of the U.S. honey crop, and commercial beekeepers in the 6 States in Scenarios III and IV produced about 13 percent of the total U.S. honey crop.[1]

## Data Base and Analytical Procedure

The effects of the assumed reduction in beeswax and honey yields were evaluated using financial records from 118 commercial beekeeping firms that operated a total of about 250,000 colonies. This sample includes firms in the States that account for about 95 percent of the commercial honey production in the area that could be colonized by the AHB. Revenues and production costs for 1971-75, as summarized by the International

Trade Commission (51), are the primary data for this analysis. Because these data were from financial records, and thus are not the same type of production cost figures agricultural economists normally use to estimate production costs, some explanation of the data is necessary.

The "production costs" (app. table 2) are actually cash operating costs (variable costs) plus depreciation claimed for income tax purposes. Owners' salaries were not included in production costs. Depreciation as claimed for tax purposes was included; as such it is based on historical costs, and no depreciation was included for assets already fully depreciated. No interest or return on investment was included except for actual interest payments on both short- and long-term debt during the 1971-75 period. Thus, the "pretax net profits" (app. table 2) are actually the sum of returns to owners' labor, management, risk, and business assets.

To estimate the net profits of these 118 firms in 1981, the 1971-75 revenues and costs were adjusted using appropriate indices of costs and returns (app. table 1). The estimated 1981 revenues from honey and beeswax sales were then reduced by 30 percent to reflect the decline in yields assumed to result from an AHB infestation. To compare the 1971-75 net profits to the estimated 1981 net profits in constant dollars, 1971-75 net profits were converted to 1981 dollars using the percentage change in the Consumer Price Index from 1971-75 to 1981.

Appendix table 1—Honey prices, production cost index, and Consumer Price Index, 1971-75 and 1981

| Item | 1971-75[1] | 1981 | Ratio, 1981 to 1971-75 average[2] |
|---|---|---|---|
| | -Cents per pound- | | Ratio |
| U.S. average honey price | 39.6 | 63.2 | 1.60 |
| | --- 1967 = 100 --- | | |
| USDA index of prices paid for production items, wages, taxes, and interest | 71.6 | 150.0 | 2.09 |
| Consumer Price Index | 137.7 | 272.4 | 1.98 |

[1]Simple average of annual data for 1971-75.
[2]Ratio of 1981 data to 1971-75 average, i.e., ratio of 1981 Consumer Price Index to 1971-75 average Consumer Price Index: 272.4/137.7 = 1.98.

Source: (49).

[1]Commercial honey production from Alabama, Louisiana, Mississippi, South Carolina, and Virginia derived from State average honey production. Commercial honey production from Arizona, California, Florida, Georgia, North Carolina, and Texas from statistics for commercial beekeepers (beekeepers operating more than 300 colonies) (46).

This analysis relies on several assumptions:

1. Honey and beeswax yields have not changed since 1971-75.

2. All revenue increased in value at the same rate as did honey prices from the 1971-75 period to 1982.

3. Beekeeping production costs increased at the same rate as the USDA index for production items, wages, taxes, and interest.

4. Yield reductions do not affect production costs except for extracting honey.

Although per colony yields increased from 1971-75 to 1981, the 95-percent confidence intervals for average yields during these two time periods overlap. That is, the 1971-75 average yields were not statistically different from 1981 yields at the 95-percent confidence level.[2]

About one-third of the "other" revenues included in the 1971-75 data were USDA pesticide indemnity payments to compensate beekeepers for bee colonies killed or damaged by pesticides. The pesticide indemnity program has been discontinued, so this source of revenue has been eliminated. The other major source of income in the 1971-75 period was pollination fees. Since then, rental fees for pollination have increased in some areas, but in others bee rental fees have remained unchanged.

The major costs for the 118 commercial beekeepers were hired labor, depreciation, sugar (for bee feed), fuel, transportation costs, and general business overhead. With the exception of sugar, most beekeeping expenses are included in the group of goods used to compute the production items index.

Production costs would fall slightly if honey and beeswax production declined by 30 percent, but not by a significant degree because most labor expense is incurred prior to harvest.[3]

### Results

From 1971-75, the 118 firms showed an annual average net profit of $2.94 million in aggregate (app. table 2). When revenues and costs are adjusted to 1981 prices, the 118 firms would have earned an estimated pretax net profit of $1.6 million in 1981.

**Appendix table 2—Profitability of commercial beekeeping, 1975-75 and 1981, with and without a 30-percent decline in honey and beeswax yields**

| Item | 1971-75[1] | 1981 (estimated) | |
|---|---|---|---|
| | | No change in honey production from 1971-75 | 30-percent decline in honey production[2] |
| | | *1,000 dollars* | |
| Revenue:[3] | | | |
| Honey and beeswax | 7,427 | 11,883 | 8,318[2] |
| Other | 1,835 | 2,936 | 2,936 |
| Total revenue | 9,262 | 14,819 | 11,254 |
| Production cost[4] | 6,321 | 13,211[5] | 12,947[6] |
| Pretax net profit (nominal dollars) | 2,941 | 1,608 | − 1,693 |
| Pretax net profit (1981 dollars) | 5,823[7] | 1,608 | − 1,693 |

[1]Simple annual average of the aggregate revenues, production costs, and net profits of 118 commercial beekeeping farms, 1971-75.

[2]Estimated 1981 revenue (column 2) reduced by 30 percent to account for the 30-percent decline in honey and beeswax yields assumed to occur in States colonized by the AHB.

[3]Revenue for 1981 estimated by multiplying the 1971-75 revenue by the ratio of honey prices, 1981 to 1971-75 (app. table 1).

[4]Production costs are comprised of cash operating costs and depreciation as claimed for income tax purposes. No interest on investment is included except for actual interest payments made during 1971-75. Owners' salaries are not included in production costs.

[5]1981 production costs estimated by multiplying 1971-75 costs by the ratio of the index for production costs, 1981 to 1971-75 (app. table 1).

[6]Production costs reduced 2 percent (see app. 2, text footnote 3).

[7]Pretax net profits are actually the total returns to owners' labor, management, risk, and return on business assets (before taxes).

Source: (52). Data for 1971-75 are from the report; 1981 data were extrapolated from these data.

[2]The confidence intervals were derived using coefficients of variation for estimates of per colony yields provided by the USDA Statistical Reporting Service (48).

[3]Enterprise budget data (4) and historical production cost data (51) indicate removing and extracting the crop account for 23 percent of hired labor expense, and hired labor accounts for about 26 percent of total costs. Thus, if honey yields decline by 30 percent (hence the amount of honey to be extracted declines by 30 percent) production costs would decline by about 2 percent, i.e., 0.23 x 0.26 x 0.3 = 0.0179.

When estimated 1981 revenues from honey and beeswax are reduced by 30 percent (to reflect the decline in production due to the AHB), the 118 firms would have suffered a net loss of $1.7 million in 1981 (app. table 2).

The 1971-75 and 1981 figures are in nominal dollars from different time periods, and thus cannot realistically be compared. By converting the net profits to constant dollars, a more accurate estimate of the change can be obtained.

The 1971-75 net profits were converted to 1981 dollars by adjusting the 1971-75 data (nominal dollars) by the percentage change in the Consumer Price Index (CPI) from 1971-75 to 1981 (app. table 1). When adjusted as described, the 1971-75 average profits of $2.94 million (nominal dollars) are equivalent to $5.8 million in 1981 dollars (app. table 2). Thus, in constant dollars the 118 firms earned nearly four times the profits in 1971-75 as they would have in 1981, assuming equal production during both time periods. This compares with an estimated net loss of about $1.7 million in 1981 if yields had been reduced by 30 percent.

Based on this analysis, the 30-percent reduction in beeswax and honey yields assumed to accompany the AHB would cause most commercial beekeeping firms in the affected States to sustain net operating losses. Under these circumstances, most commercial beekeepers in the affected States would go out of business unless honey prices increased significantly or beekeepers developed other sources of income.

About half of the assets of beekeeping firms have essentially no use in any other enterprise (31). Firms liquidating in a general industry decline could find as much as 50 percent or more of their assets would have little or no salvage value, adding to the hardship of going out of business. This surplus of beekeeping equipment would also depress the value of assets owned by other beekeeping firms in States not colonized by the AHB.

## Price Changes Necessary to Avoid Economic Losses

As described, commercial beekeeping firms in the area with AHB would suffer net operating losses if honey and beeswax production declined by 30 percent. When the supply of a good drops, its price generally rises. The following secton analyzes the price changes necessary to restore the profitability of commercial beekeeping to the estimated 1981 level (at current levels of production) and to the zero-profit level. These prices are computed assuming a 30-percent decline in yields.

## Price Necessary to Maintain Current Profits

Although honey and beeswax production were assumed to decline by 30 percent, prices would have to increase by more than 30 percent to maintain profitability. The following example explains how the necessary price change is determined.

A firm's total revenue is computed:

$$TR_1 = Q_1 P_1 \tag{1}$$

where:

$TR_1$ = total revenue in time period 1
$Q_1$ = quantity produced in period 1
$P_1$ = price in period 1

If a firm's output in a later time period, $(t_2)$, is reduced by 30 percent compared to time period $t_1$, the total revenue, in $t_2$ ($TR_2$), is computed (price remaining constant):

$$TR_2 = 0.7 Q_1 P_1 \tag{2}$$

If $TR_2$ is to equal $TR_1$, the price in period 2 ($P_2$) must increase. Given $TR_2 = 0.7 Q_1 P_1$ and $TR_1 = Q_1 P_1$, equating $TR_1$ to $TR_2$:

$$TR_2 = TR_1, \tag{3}$$

and substituting these identities yields the equation:

$$0.7 Q_1 P_2 = Q_1 P_1 \tag{4}$$

which rearranged yields the new price, $P_2$:

$$P_2 = \frac{Q_1 P_1}{0.7 Q_1} = \frac{P_1}{0.7} = 1.43 P_1 \tag{5}$$

Thus, although production declines by 30 percent, the unit price must increase by 43 percent for revenues and profits in $t_2$ to equal those in $t_1$.

Given the 1981 U.S. average honey price of 63.2 cents per pound, if production declined by 30 percent, the honey price would have to rise to 90.4 cents per pound (1.43 x 63.2 cents per pound = 90.38) to restore revenues and profits to predecline levels. This price, 90.4 cents per pound, is more than twice the 1981 world price of honey (about 40 cents per pound) and is 45 percent higher than the 1981 U.S. price (2,50).

## Price Necessary to Break Even

For a honey-producing firm facing a decline in production that causes a net loss, the price necessary to restore that firm to zero profitability is derived from the following equation:[4]

$$P_{be} = \frac{(TR + NL)}{Q} \tag{6}$$

where:

$P_{be}$ = break-even price, dollars per pound
$TR$ = total revenue in dollars
$NL$ = net loss in dollars
$Q$ = honey production in pounds[5]

For the 118 firms evaluated, revenue from honey and beeswax sales for 1981 (assuming a 30-percent yield decline) is an estimated $8.318 million and the net loss for those firms is estimated at $1.693 million (app. table 2). At the 1981 U.S. average honey price of 63.2 cents per pound (and ignoring the minor contribution of beeswax sales to total revenue), this revenue corresponds to honey production of about 13.2 million pounds ($8,318,000 ÷ $0.632 per pound = 13,161, 392 pounds). Substituting these values into (6) yields the breakeven price:

$$P_{be} = \frac{(\$8,318,000 + \$1,693,000)}{13,161,392 \text{ pounds}} \tag{7}$$
$$= \$0.761 \text{ per pound.}$$

Thus, if yield declined by 30 percent, a honey price of 76.1 cents per pound would be necessary to restore the 118 firms studied to a zero-profit level at 1981 production costs. This is almost twice the 1981 world price and is about 21 percent higher than the 1981 U.S. average price.
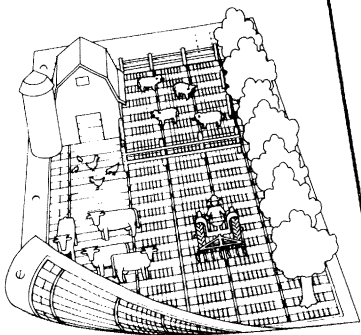
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[4]A zero-profit level would allow the firm to pay all cash operating cost except the operator's labor.

[5]This analysis ignores the minor contribution of beeswax sales to total revenue.

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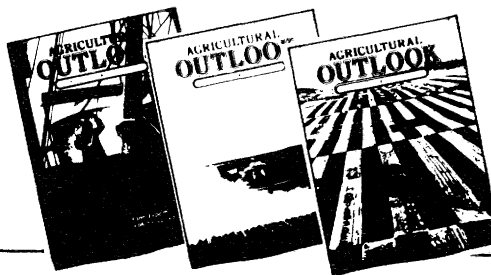> U.S. Government Printing Office
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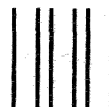
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